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The Effects of Plain Sedimentation on the Quality of Urban Stormwater Runoff from the Lake Eola Watershed

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THE EFFECTS OF PLAIN SEDIMENTATION ON THE QUALITY OF URBAN STORMWATER RUNOFF FROM THE LAKE EOLA WATERSHED

BY

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THESIS

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ABSTRACT

The settling characteristics of urban stormwater runoff emanating from the Lake Eola Watershed (Orlando, Florida) were evaluated through a series of 7 column studies. The percentage removal that occurred due to sedimentation was observed for various stormwater pollutants and constituents. These included the General Water Quality Parameters: Total Suspended Solids, Non-volatile Suspended Solids, Volatile Suspended Solids, Chemical Oxygen Demand, Total Kjeldahl Nitrogen, Ammonia Nitrogen, Total Organic Carbon, and Total Phosphorus. The metals parameters: Zinc, Cadmium, Arsenic, Nickel, Copper, Magnesium, Iron, Lead, Chromium and Calcium were also considered. The results of the settling analysis indicates that the quality of Lake Eola stormwater can be improved by plain sedimentation or detention as convincing removals were displayed by the solids parameters and total phosphorus. Significant lead removal was achieved throughout the column studies; however, the balance of the metals parameters displayed trends of weak removal. Regression equations were developed that describe percent removal as a linear and logarithmic function of time and settling velocity. Isoconcentration lines were also developed for total suspended solids and total phosphorus removals. In addition, the effect of this treatment on the productivity of Lake Eola was assessed in terms of existing trophic state models.

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CHAPTER I

INTRODUCTION

Eutrophication refers to the natural or artificial addition of nutrients to bodies of water and to the resulting effects of nutrient enrichment. It is a natural aging process that can be greatly accelerated by man and his activities. Urban stormwater runoff is partially to blame for cultural eutrophication in many cases. Stormwater runoff and other non-point sources of pollution have attained somewhat of a notoriety in recent years; and they have become the focal point for extensive research and legislation.

The degradation of surface waters throughout the U.S. by discharges of both point and non-point origin prompted Congress to enact Public Law 92-500, the Federal Water Pollution Control Act Amendments of 1972. Section 208 of PL 92-500 provides for the promulgation of comprehensive, areawide plans for water pollution control and management.

The Orlando Metropolitan Areawide 208 Water Quality Management Plan recognized that future control over non-point sources will only serve to maintain the existing non-point pollutant loadings to the area's surface waters. Therefore, the plan calls for a systematic reduction in current stormwater pollutant loadings to that which approaches natural background levels by the year 2000. To attain this goal a need was expressed for Lake Restoration Programs to deal with the nutrients currently within lakes. One such restoration program is presently being implemented on Lake Eola located in downtown Orlando, Florida (see Figure I-1).

The Lake Eola project has been jointly sponsored by the United States Environmental Protection Agency, the Florida Department of Environmental Regulation, the City of Orlando and the University of Central Florida.

Restoration activities are not new to Lake Eola. The lake was considered eutrophic in 1972 due to silt deposits, aesthetic conditions of the bottom and frequent algae blooms (Wanielista, 1973). At that point, the lake level was drawn down; sediments were removed and replaced by sand; bottom contours were improved and the lake was refilled with clean well water. Littoral zone vegetation were introduced and the lake was stocked with fish. The restoration achieved some limited success, despite the fact that the source of pollution, namely stormwater runoff, was not removed or the effects thereof mitigated. Hence, eutrophication took its course and once again the restoration of Lake Eola is in the forefront.

Purpose

A comprehensive Lake Restoration Plan must include some provision for the evaluation of pollution abatement measures.

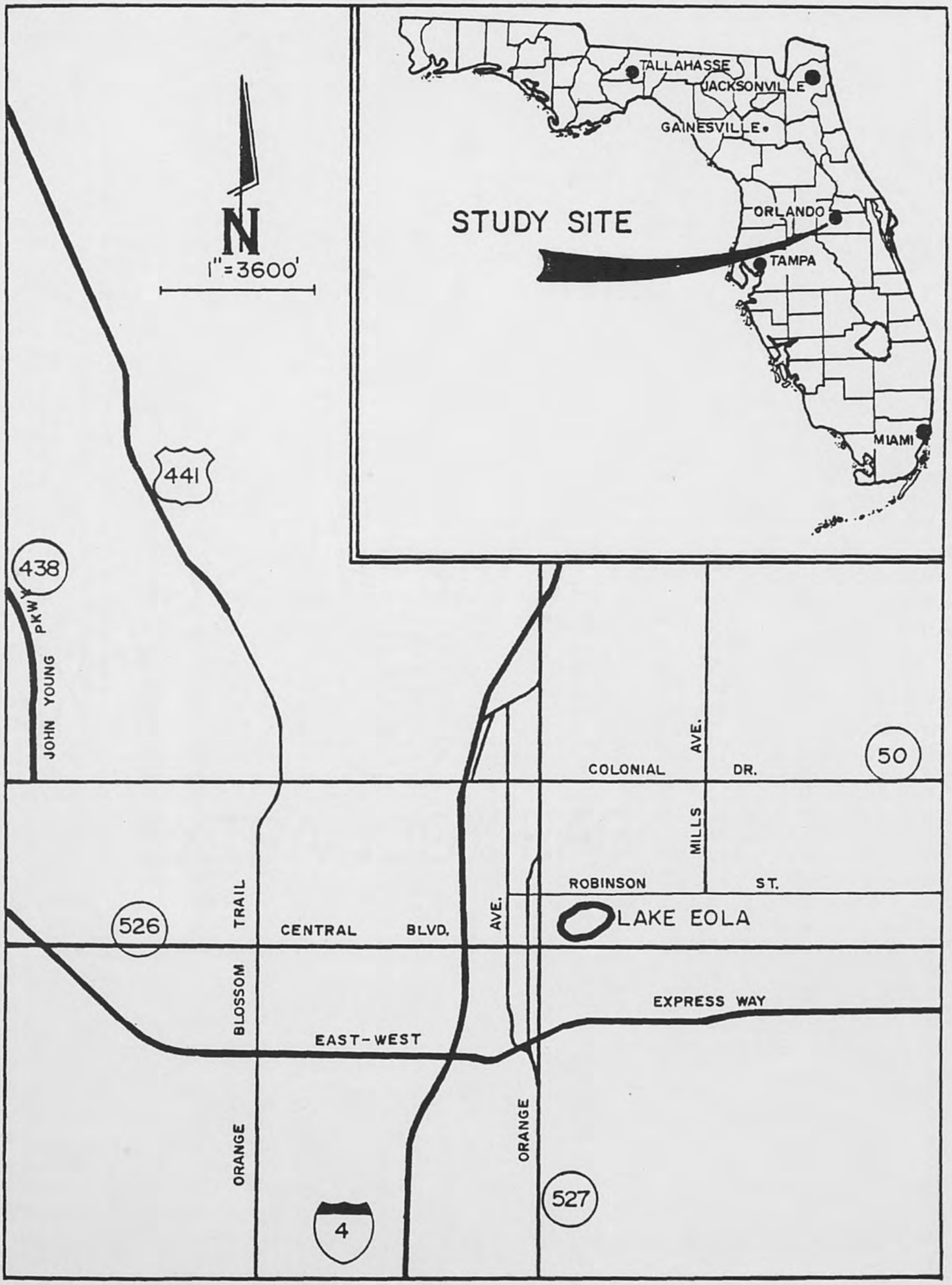


Fig. I-1. Lake Eola location map.

Nutrient laden urban stormwater runoff has exerted a marked influence on the productivity of Lake Eola. Therefore, to maintain the integrity of the lake after restoration, it has been proposed that stormwater receive treatment by some mechanism to remove deleterious constituents before discharge. The ideal treatment methodology will be one that will accrue the most benefit to water quality in the most cost effective manner.

Stormwater runoff from the Lake Eola watershed was considered amenable to treatment by certain technologies or best management practices. This thesis represents research that was conducted to evaluate plain sedimentation or detention of stormwater prior to lake discharge. This was accomplished strictly from the standpoint of removal efficiency; costs were not considered. The data gathered by this study will ultimately lead to the rejection or selection of sedimentation (detention) as a viable treatment alternative for Lake Eola runoff. The removal behavior exhibited by settled runoff from the Lake Eola watershed will be typical of most urban runoff suspensions. Thus, the results of this investigation may assist future stormwater treatment evaluations for other urban lakes.

CHAPTER II

LITERATURE REVIEW

Gravity separation or sedimentation refers to the removal of suspended solids whose specific gravity difference from that of water causes them to settle during passage through a tank or basin under quiescent conditions (U.S. EPA, 1975). Sedimentation has received widespread application in wastewater and potable water treatment processes. However, the current emphasis on non-point source pollution abatement suggests that this unit process may acquire further application in the treatment of stormwater runoff. Although the performance of stormwater settling facilities is difficult to predict due to the site specific nature of stormwater, the design of these facilities must certainly address the theoretical aspects of the process.

Sedimentation Theory

Settling is described according to the suspension concentration and the stability of the suspended particles (Weber, 1972). Four regimes of settling have been identified and predicated on this criteria. The removal of discrete particles out of a dilute suspension is known as Class-I clarification (Weber, 1972). Class-I settling involves stable particles that do not flocculate;

however, particles that do tend to flocculate during settling undergo what has been termed Class-II clarification (Weber, 1972).

Interparticle forces may be of such a nature that the position of each suspended particle will remain constant relative to the others. Consequently, the suspension settles out as a mass, rather than as discrete particles. This type of clarification has been termed zone settling. When particles begin to make contact, and the weight of the settled matter is partially supported by the structure of the compacting mass, compression settling has occurred (Rich, 1961). Class-I and Class-II settling were of primary interest during this investigation.

The settling behavior of a discrete particle placed in a quiescent fluid is merely a function of fluid properties and particle characteristics (Weber, 1972). The particle will accelerate to a terminal velocity at which point equilibrium is reached between fluid drag forces and the particle driving force.

The driving force is the resultant derived from the downward force exerted by particle weight, and the buoyant force directed upward by the fluid. This relationship is described by equation 1.

$$F = (\rho_s - \rho_l)V_p g \tag{1}$$

where:

F = Driving Force

ρ_s = Particle Density

ρ_l = Fluid Density

V_p = Particle Volume

g = Acceleration due to Gravity

The frictional or drag force is a function of particle roughness, size, shape, velocity, fluid density and fluid viscosity. The fluid drag force is dimensionally expressed as:

$$F_d = \frac{C_d A_p \rho_l V_t^{\,2}}{2} \tag{2}$$

where: F_d = Drag Force

C_d = Newton's Drag Coefficient

A_p = Projected area of the particle in the direction of motion

V_t = Terminal Subsidence Velocity

Equating the driving force and the drag force yields the following expression:

$$(\rho_s - \rho_l)V_p g = (C_d A_p \rho_l V_t^{\,2})/2 \tag{3}$$

A relationship which describes the settling velocity of a discrete particle can be found by rearranging terms in the equation above.

$$V_t = \sqrt{\frac{2g(\rho_s - \rho_l)}{C_d \rho_l}\left(\frac{V_p}{A_p}\right)} \tag{4}$$

If spherical particles of diameter, d_p, are considered under laminar flow conditions, Stoke's Law of Settling will result. Substituting equations 5 and 6 into equation 4 yields the following expression for terminal velocity (equation 7).

$$\frac{V_p}{A_p} = \frac{2d_p}{3} \tag{5}$$

where: V_p = Particle Volume

A_p = Particle Area

d = Particle Diameter

$$C_d = \frac{24}{N_r} = \frac{24\mu}{d_p \rho_l V_t} \qquad (6)$$

where: N_r = Reynolds Number = $d_p \rho_l V_t / \mu$

μ = Fluid Viscosity

$$V_t = \frac{g}{18\mu} (\rho_s - \rho_l) d_p^{\,2} \qquad (7)$$

Equation 7 is known as Stoke's Law.

According to Rich (1961), at Reynolds numbers less than 0.1, in the region often called the Stoke's Law range, the fluid will flow smoothly over the surface of the sphere, leaving no wake. Therefore, particles that can be described by Stoke's Law have minimal fluid drag forces associated with them.

Class-I clarification is independent of settling basin depth and is dependent only on the surface area of the basin and on particle settling velocity (Rich, 1961). The following expression for the rate of clarification illustrates this relationship:

$$Q = \frac{z}{t} A = V_t A \qquad (8)$$

where: Q = Volumetric Rate of Clarification, (ft^3/sec)

t = Time, seconds

A = Cross-sectioned area of volume in a plane perpendicular to the direction of subsidence, (ft^2)

z = Distance through which particles settle in time (t)

Sedimentation basins are designed to provide some rate of clarification, q_2, commonly referred to as the overflow rate. A terminal settling velocity, V_{t_2}, will be associated with this overflow rate. When liquid is withdrawn at a rate equivalent to q_2, particles with settling velocities equal to or higher than V_{t_2} will be completely removed. Particles with some lower settling velocity, V_{t_1}, will be removed in proportion to the ratio V_{t_1}/V_{t_2}.

Settling Column Studies

Theoretical laws do not adequately predict settling characteristics for Class-II clarification. The constituents in suspension, whether it is domestic wastewater, industrial wastewater, or stormwater runoff, are very diversified. Hence, particle settling rates are equally as diverse.

Particle interaction during subsidence is a common occurrence. The settling motion of one particle may be interrupted due to the settling behavior of another. Settling interference of this type is known as hindered settling and is characteristic of Class-II clarification.

Particle agglomeration may also occur as settling progresses. Typically, particles with higher settling rates overtake and coalesce with slower particles resulting in an increase in particle mass. Accompanying this mass increase is a corresponding increase in particle settling velocity. This phenomenon is referred to as flocculent settling.

Particles may also lose mass during subsidence as fluid shear forces break up flocculated particles. Thus, it is apparent that the characteristics of Class-II suspensions inhibits accurate mathematical modeling. In order to fully evaluate the settling behavior of a suspension, settling column tests are required.

Settling column analyses generally involve the placement of a completely mixed sample into a 6 foot to 8 foot long column. Column diameters can vary; however, 4 inch to 6 inch diameters are necessary if wall effects are to be neglected (Zanoni and Biomquist, 1975). As many as 7 sampling ports may be arranged at various depths along the column. Zanoni and Biomquist (1975) determined that 3 sampling ports were sufficient to describe removal behavior. The suspension is permitted to settle quiescently for a selected period of time. At pre-determined intervals during the study period, samples are simultaneously removed at each of the ports.

Column studies are not exclusively used to describe the removal behavior of suspended solids. They may be used to describe the removal characteristics of any constituent in suspension, such as total phosphorus, total kjeldahl nitrogen or chemical oxygen demand.

If the initial particle or constituent concentration and the concentration associated with the sampling time is known, the fraction removed at each sampling port depth can be determined. Percentage removals are then plotted for each depth as a function of time. Subsequently, lines of equal percentage or isoconcentration lines can be drawn on these plots as shown in Figure II-1. Weber (1972) describes these lines as the maximum settling path for the indicated removal, and the depth-time ratio as the minimum average settling velocity. The curvilinear lines in Figure II-1 indicate that flocculent settling is occurring and that settling velocity is changing with time (Zanoni and Biomquist, 1975).

Figure II-1 indicates that R_d^o of the particles have average settling velocities greater than V_o and will consequently be removed completely. Particles situated between R_c^o and R_d^o and between R_d^o and R_e^o have average settling velocities of h_a/t_2 and h_b/t_2, respectively. The total overall removal is given by equation 9 below.

$$R^o = R_c + \frac{h_a}{t_2 v_o}(R_d^o - R_c^o) + \frac{h_b}{t_2 v_o}(R_c^o - R_d^o) \qquad (9)$$

Stormwater Quality and Sedimentation Applications

The impact of urbanization and the associated stormwater runoff on lakes is vividly illustrated by the following case study

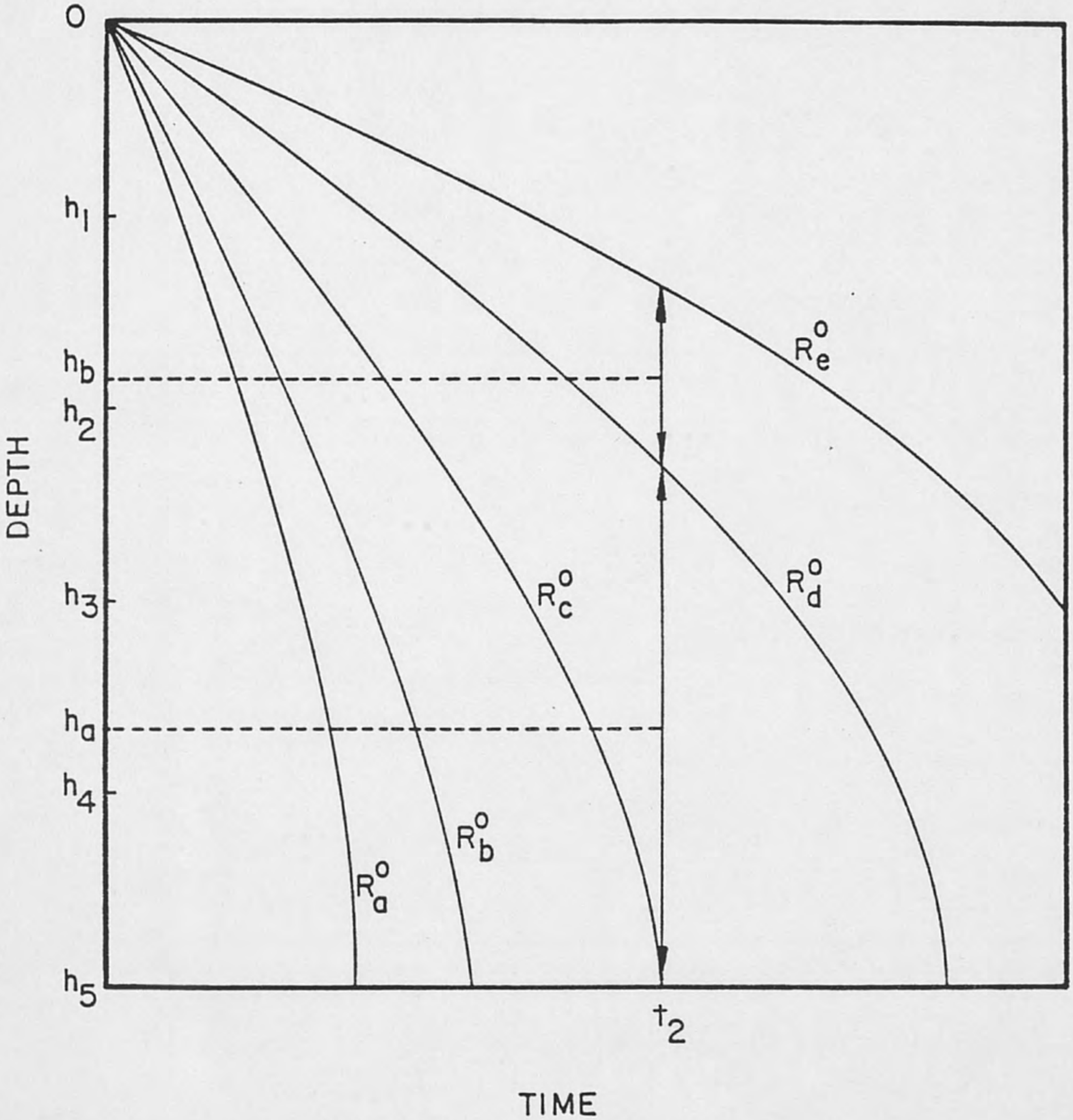


Fig. II-1. Typical plot of percent removal versus time with isoconcentration lines.

SOURCE: Weber, Walter J. Physicochemical Processes for Water Quality Control. New York: John Wiley & Sons, Inc., 1972.

pertaining to Lake Boone (Malcolm and Smallwood, 1977). Lake Boone was located in Raleigh, North Carolina where it was impounded in 1930. It had a drainage area of 1.8 square miles; but, as the years advanced, the once rural setting slowly became urbanized. The lake's 1930 volume of 45 acre-feet diminished gradually over the years until 1955 when the lake's volume was almost entirely occupied by sediment. Lake Boone had a life of 25 years during a condition of gradual development. Malcolm and Smallwood (1977) estimated that its life would have extended to 71 years if the drainage area had retained its rural character.

The plight of Lake Boone clearly indicates the need for sedimentation control in urban watersheds. Corrective measures may include the maintenance of cover vegetation, the use of overland flow for stormwater conveyance, the installation of catch basins and the use of detention basins. The selection of the proper management technique requires knowledge of the sources and the characteristics of stormwater pollutants.

Sartor and Boyd (1972) identified several sources of street surface contaminants. Among these were: the pavement itself, motor vehicles, atmospheric fallout, vegetation, runoff from adjacent land areas, litter, spills, and anti-skid compounds. The particle size distribution of street surface contaminants is an important characteristic. The size of polluting solids determines, to a great extent, the efficacy of certain stormwater management practices, such as sedimentation or detention. Table II-1 lists

TABLE II-1

PARTICLE SIZE DISTRIBUTION OF SOLIDS
SELECTED CITY COMPOSITES

Size Ranges	Milwaukee	Bucyrus	Baltimore	Atlanta	Tulsa
> 4,800 µ	12.0%	-----	17.4%	-----	-----
2,000-4,800 µ	12.1%	10.1%	4.6%	14.8%	37.1%
840-2,000 µ	40.8%	7.3%	6.0%	6.6%	9.4%
246-840 µ	20.4%	20.9%	22.3%	30.9%	16.7%
104-246 µ	5.5%	15.5%	20.3%	29.5%	17.1%
43-104 µ	1.3%	20.3%	11.5%	10.1%	12.0%
30-43 µ	4.2%	13.3%	10.1%	5.1%	3.7%
14-30 µ	2.0%	7.9%	4.4%	1.8%	3.0%
4-14 µ	1.2%	4.7%	2.6%	0.9%	0.9%
< 4 µ	0.5%	-----	0.9%	0.3%	0.1%

SOURCE: Sartor, James D., and Gail B. Boyd. Water Pollution Aspects of Street Surface Contaminants. Washington, D.C.: U.S. Environmental Protection Agency, U.S. Government Printing Office, 1972.

the particle size distribution of polluting solids for selected cities in the United States. If the values presented in Table II-1 are averaged, it is evident that approximately 57.9 percent of the particles have sizes which exceed 246 microns (μ). Nearly 28.6 percent of the particles belong to the range of 43μ to 246μ. The remaining 13.5 percent of the particles have sizes below 43μ. The fraction of pollutants associated with various particle ranges are presented in Table II-2. A similar listing for heavy metals can be found in Table II-3.

Dalrymple et al. (1975), indicated that if stormwater runoff contains fine and coarse sand, 40 microns and greater in size, separation by sedimentation should be easily accomplished. Referring to Table II-2, it is apparent that 56.2 percent of the phosphates by weight in dry street contaminants, were associated with particle sizes of 43μ or less. Furthermore, 18.7 and 31.9 percent by weight of kjeldahl nitrogen and nitrate nitrogen, respectively, were composed of particles with sizes of 43μ or less. Therefore, the foregoing percentages represent the fraction of each constituent that potentially will not be removed by settling or detention.

From Table II-2, only 5.9 percent of the total solids by weight were included in the 43μ or less range. However, 56.2 percent of the phosphates by weight were represented by this small fraction of solids.

TABLE II-2

FRACTION OF POLLUTANT ASSOCIATED
WITH EACH PARTICLE SIZE RANGE
(% by Weight)

	Particle Size (μ)					
	>2,000	840→2,000	246→840	104→246	43→104	< 43
Total Solids	24.4	7.6	24.6	27.8	9.7	5.9
Volatile Solids	11.0	17.4	12.0	16.1	17.9	25.6
BOD_5	7.4	20.1	15.7	15.2	17.3	24.3
COD	2.4	4.5	13.0	12.4	45.0	22.7
Kjeldahl Nitrogen	9.9	11.6	20.0	20.2	19.6	18.7
Nitrates	8.6	6.5	7.9	16.7	28.4	31.9
Phosphates	0.0	0.9	6.9	6.4	29.6	56.2
Total Heavy Metals	16.3	17.5	14.9	23.5	27.8	
Total Pesticides	0.0	16.0	26.5	25.8	31.7	

SOURCE: Sartor, James D., and Gail B. Boyd. Water Pollution Aspects of Street Surface Contaminants. Washington, D.C.: U.S. Environmental Protection Agency, U.S. Government Printing Office, 1972.

TABLE II-3

FRACTION OF HEAVY METALS ASSOCIATED
WITH EACH PARTICLE SIZE RANGE
(% by Weight)

	Particle Size (μ)				
	>2,000	840→2,000	246→840	104→246	<104
Chromium	26.1	13.6	16.3	16.3	27.7
Copper	22.5	20.0	16.5	19.0	22.0
Zinc	4.9	25.9	16.0	26.6	26.6
Nickel	26.2	14.2	15.3	17.2	27.1
Mercury	16.4	28.8	16.4	19.2	19.2
Lead	1.7	2.6	8.7	42.5	44.5
Average	16.3	17.5	14.9	23.5	27.8

SOURCE: Sartor, James D., and Gail B. Boyd. Water Pollution Aspects of Street Surface Contaminants. Washington, D.C.: U.S. Environmental Protection Agency, U.S. Government Printing Office, 1972.

Cowen and Lee (1976) investigated the availability of phosphorus in particulates transported by urban runoff in Madison, Wisconsin. Runoff was filtered through 0.45μ pore size membrane filters. The residue was then resuspended in phosphorus free algal assay procedure medium wherein a suspension of *Selenastrum capricornutum* was added. Thirteen algal bioassays were performed on stormwater runoff. The overall average was 30 percent of particulate phosphorus available to *Selenastrum* in 19 to 22 days (Cowen and Lee, 1976).

The findings of Cowen and Lee (1976), combined with those of Sartor and Boyd (1972), suggest that a stormwater detention or sedimentation facility effectively could remove 43.8 percent of particulate phosphates by weight. Moreover, of this 43.8 percent, only 30 percent is actually available to receiving water biota. Hence, the available phosphorus removed by sedimentation or detention will account for only 13.1 percent of the total particulate phosphorus.

The efficiency of stormwater detention basins as a function of particle size and basin depth was investigated by Curtis and McCuen (1977). Their investigation of particle size effects involved the use of two weight fraction distributions of particles. Distribution A had 70 percent of its particles in the 750 to 94 micron range; whereas, 75 percent of distribution A's particles were within the range of 1500 to 137 microns. Particle density remained constant for each particle size. Curtis and McCuen (1977) found that trap efficiency, the ratio of sediment retained in the basin to the weight of the sediment reaching the basin, was higher for distribution B. These results produced the conclusion that the effectiveness of a particular detention basin is dependent on particle size and weight distribution. Furthermore, their investigation of basin depth effects indicated a significant relationship between trap efficiency and depth. Overall trap efficiency improved from 54 percent to 75 percent as basin depth dropped from 15 feet to 7 feet. The shallower depth required a larger surface area which extended the horizontal flow distance and shortened the vertical flow distance. Consequently, more particles were settled out.

Suspended solids removal efficiencies for sedimentation/detention facilities also depend on the storage volume and the surface loading rate (Wanielista, 1978). Reasonable estimates of suspended solids removal efficiencies are 60 to 75 percent at 1000 gal/ft^2-day, 20 to 30 percent at 2000 gal/ft^2-day and 10 to 20 percent at 3000 gal/ft^2-day (Wanielista, 1978).

Detention tanks have also been proposed for management purposes. Details were not given for their design; however, tanks with capacities ranging from 2500 gallons per acre to 25,000 gallons per acre have been reported to produce 37 percent to 67 percent suspended solids removal (Willison, 1977). Removals of BOD were reported to range from 18 to 39 percent for the same tank capacity range (Willison, 1977).

Lager and Smith (1974), in their assessment of urban stormwater management and technology, conclude that physical treatment processes, such as sedimentation, are well suited to stormwater applications. It was also stated that removal efficiencies for the physical treatment processes tend to vary directly with the influent contaminant concentration. Therefore, instantaneous removal efficiencies lose their significance; an improved basis of comparison is mass loadings applied versus those discharged.

Lager et al. (1977) concluded that physical treatment systems have the capability to handle high and variable influent concentrations and flow rates. They reported percent reductions due to plain sedimentation of 20 to 60 percent and 30 to 90 percent for suspended and settleable solids, respectively. Total phosphorus and total kjeldahl nitrogen removals were 20 and 38 percent, respectively; BOD_5 was diminished by 30 percent and COD by 34 percent. Removal of heavy metals, nitrogen, phosphorus and other constituents by sedimentation are summarized in Table II-4.

A study conducted by Colston and Tafuri (1974) on the Third Fork Creek drainage basin in Durham, North Carolina, produced significant data concerning the physical treatment of urban stormwater runoff. Land uses associated with the basin were varied and included: high and low density housing, shopping centers, portions of the central business district, industry, railroad

TABLE II-4

POLLUTANT REMOVAL FOR VARIOUS CONSTITUENTS BY PLAIN SEDIMENTATION

Pollutant	Average Removal (%)
Heavy Metals[a]	
Copper	24.1
Chromium	32.3
Nickel	26.6
Zinc	27.2
Lead	30.6
Iron	16.6
Cadmium	38.8
Calcium	19.2
Magnesium	23.5
Sodium	18.5
Potassium	23.5
Mercury	8.4
Nitrogen[b]	
Ammonia	22.1
Organic	50.5
Total Kjeldahl	38.4
Nitrate	15.4
Nitrite	0.0
Phosphorus[b]	
Total	22.2
Ortho	6.7
Other Constituents[b]	
COD	34.4
TOC	21.3
Oil and Grease[c]	11.9

[a] Average of 10 samples.
[b] Average of 2 to 3 samples.
[c] Average of 6 samples.

SOURCE: Lager, John A., et al. Urban Stormwater Management and Technology: Update and Users' Guide. Washington, D.C.: U.S. Environmental Protection Agency, U.S. Government Printing Office, 1977.

yards, expressways and undeveloped land. The average concentrations of pollutants contained in stormwater runoff from the Third Fork Creek basin are listed in Table II-5.

Removals for COD, suspended solids and turbidity were 61, 77 and 53 percent, respectively, for 15 minutes of plain sedimentation under ideal quiescent conditions. Furthermore, Colston and Tafuri (1974) concluded that plain sedimentation, being less costly than chemical coagulation, removed a significant portion of organics and should be considered as the first alternative in treatment of urban land runoff.

Best management practices for non-point source pollution control were evaluated in the Orlando Metropolitan Areawide 208 Water Quality Management Plan (East Central Florida Regional Planning Council, June 1978). The performance of a sedimentation basin discharging to Prairie Lake in Casselberry, Florida was included as part of these evaluations. The treatment facility was serving a 4.4 acre commercial area during the investigation. Typical pollutant loadings for the Prairie Lake drainage basin are listed in Table II-6.

The sedimentation basin measured 38 feet in length and 18 feet in width. The basin bottom sloped upward from a depth of 6 feet at the influent end to 6 inches at the effluent end. A baffle was included to prevent the short circuiting of flows and to act as an energy dissipator.

TABLE II-5

AVERAGE, RANGE, AND STANDARD DEVIATION OF POLLUTANT CONCENTRATIONS IN RUNOFF SAMPLED FROM THE THIRD FORK CREEK BASIN, DURHAM, N.C.

Pollutant	Mean mg/l	Standard Deviation	Range (mg/l)	
			Low	High
COD	170	135	20	1042
TOC	42	35	5.5	384
Total Solids	1440	1270	194	8620
Volatile Solids	205	124	33	1170
Total Suspended Solids	1223	1213	27	7340
Volatile Suspended Solids	122	100	5	970
Kjeldahl Nitrogen as "N"	.96	1.8	.1	11.6
Total Phosphorus as "P"	.82	1.0	.2	16
Fecal Coliform (#/ml)	230	240	1	2000
Aluminum	16	8.15	6	35.7
Calcium	4.8	5.6	1.1	31
Cobalt	.16	.11	.04	.47
Chromium	.23	.10	.06	.47
Copper	.15	.09	.04	.50
Iron	12	9.1	1.3	58.7
Lead	.46	.38	0.1	2.86
Magnesium	10	4.0	3.6	24
Manganese	.67	.42	.12	3.2
Nickel	.15	.05	.09	.29
Zinc	.36	.37	.09	4.6
Alkalinity	56	30	24	124

SOURCE: Colston, Newton V., Jr., and Anthony N. Tafuri. Characterization and Treatment of Urban Land Runoff. Washington, D.C.: U.S. Environmental Protection Agency, U.S. Government Printing Office, 1974.

TABLE II-6

POLLUTANT LOADINGS FOR THE PRAIRIE LAKE COMMERCIAL DRAINAGE BASIN

Constituent	Loading (lb/Ac-yr)
BOD_5	96.5
Suspended Solids	4056.0
Total Nitrogen	29.6
Total Phosphorus	10.9

SOURCE: East Central Florida Regional Planning Council. Orlando Metropolitan Areawide 208 Water Quality Management Plan. Winter Park: East Central Florida Regional Planning Council, June 1978.

Six storm events were sampled at the site; influent and effluent loadings are shown in Table II-7 for BOD_5, Total Nitrogen, Total Phosphorus and Suspended Solids. Removal efficiencies for these parameters were 60, 76, 76 and 84 percent, respectively. It was determined that removal efficiencies would improve significantly if the sedimentation basin was drained and cleaned between rainfall events (Wanielista and Shannon, 1977). This would eliminate the resuspension of sediment that occurred as a result of the scouring action produced by incoming flow.

Lake Eola

Lake Eola is a land-locked water body situated in the central business district of Orlando, Florida. It is a notable downtown amenity and is characterized by a surrounding park and gardens including a concert band shell. The lake, with its unique water fountain, is a familiar Orlando landmark and is the site for numerous community activities.

The Central Florida area has a subtropical climate with winter and summer as the only apparent seasons. The average temperature in Orlando is 71.5^{o} F (U.S.G.S., 1968). The average annual areal rainfall amounts to 51.4 inches (U.S.G.S., 1968). Approximately 50 percent of this annual precipitation occurs during the summer wet season, which extends from June through September. Thunderstorms occur on an average of 83 days per year, one of the highest incidences of storms in the United States (U.S.G.S., 1968).

TABLE II-7

INFLUENT AND EFFLUENT LOADINGS WITH AVERAGE EFFICIENCIES FOR THE PRAIRIE LAKE SEDIMENTATION BASIN

Constituent	Influent Load (lbs/yr)	Effluent Load (lbs/yr)	Average Efficiency %
BOD_5	425.0	171.2	60
Suspended Solids	17,884.4	2,936.5	84
Total Nitrogen	130.3	31.4	76
Total Phosphorus	48.0	11.6	76

SOURCE: East Central Florida Regional Planning Council. Orlando Metropolitan Areawide 208 Water Quality Management Plan. Winter Park: East Central Florida Regional Planning Council, June 1978.

Monthly temperature and rainfall values for the City of Orlando are summarized in Table II-8.

Lake Eola has a capacity of about 100 million gallons and an approximate surface area of 27 acres. The water surface elevation fluctuates between 87.5 feet and 88.5 feet above mean sea level with regulation provided by 3 drainage wells. Lake depth varies from a maximum of 22 feet to a shore line depth ranging between 2 and 3 feet. A map depicting lake water depth is shown in Figure II-2. A bulk head extending along the perimeter of the lake disrupts the stratification of the littoral zone by preventing the formation of beaches. However, emergent vegetation does exist desultorily in the shallow depths which abut the perimeter wall. Swimming, fishing, boating, and other related activities are not normally permitted on Lake Eola. Lake use is essentially limited to sightseeing.

The Lake Eola Watershed, including Eola Park, comprises 148 acres. The land uses associated with the watershed are largely commercial, residential, and parkland. Land use areas and watershed boundaries are delineated in Figure II-3.

The predominant soil types found in the Orlando area are Lakeland, Eustis, Blanton and Orlando (S.C.S., 1960). These soils have subsequently been classified into The Soil Conservation Service Hydrologic Group A (S.C.S., 1975). Soils that are members of this group have a high infiltration rate even when thoroughly wetted and consist chiefly of deep, well drained to excessively drained sands

TABLE II-8

TEMPERATURE AND RAINFALL AT ORLANDO, FLORIDA

	Normal Daily Maximum Temperature[1,3]	Normal Daily Minimum Temperature[2]	Normal Average Temperature[1,2]	Normal Rainfall Inches[1,2]	Minimum Rainfall[3]			
					Inches	Year	Inches	Year
January	70.7	50.0	60.4	2.00	6.44	1948	0.15	1950
February	72.0	50.7	61.4	2.42	5.64	1960	0.10	1944
March	75.7	54.0	64.9	3.41	10.54	1960	0.16	1956
April	80.5	59.8	70.2	3.42	6.18	1953	0.28	1961
May	75.9	66.2	76.1	3.57	8.58	1957	0.43	1961
June	89.1	71.4	80.3	6.96	13.70	1945	1.97	1948
July	89.9	73.0	81.5	8.00	19.57	1960	3.83	1963
August	90.0	73.5	81.8	6.94	15.19	1953	3.20	1960
September	87.6	72.4	80.0	7.23	15.87	1945	1.65	1958
October	82.6	65.3	74.0	3.96	14.51	1950	0.46	1963
November	75.6	56.2	65.9	1.57	6.39	1963	0.09	1950
December	71.6	51.2	61.4	1.89	4.30	1950	Trace	1944
Yearly	80.9	62.0	71.5	51.37	68.74	1960	39.61	1943

1 Average for 10 or more years
2 U.S. Weather Bureau records, 1931-1960.
3 U.S. Weather Bureau records, 1943-1960.

SOURCE: United States Geological Survey. Water Resources of Orange County, Florida. Deland, FL: Florida Board of Conservation, Division of Geology, 1968.

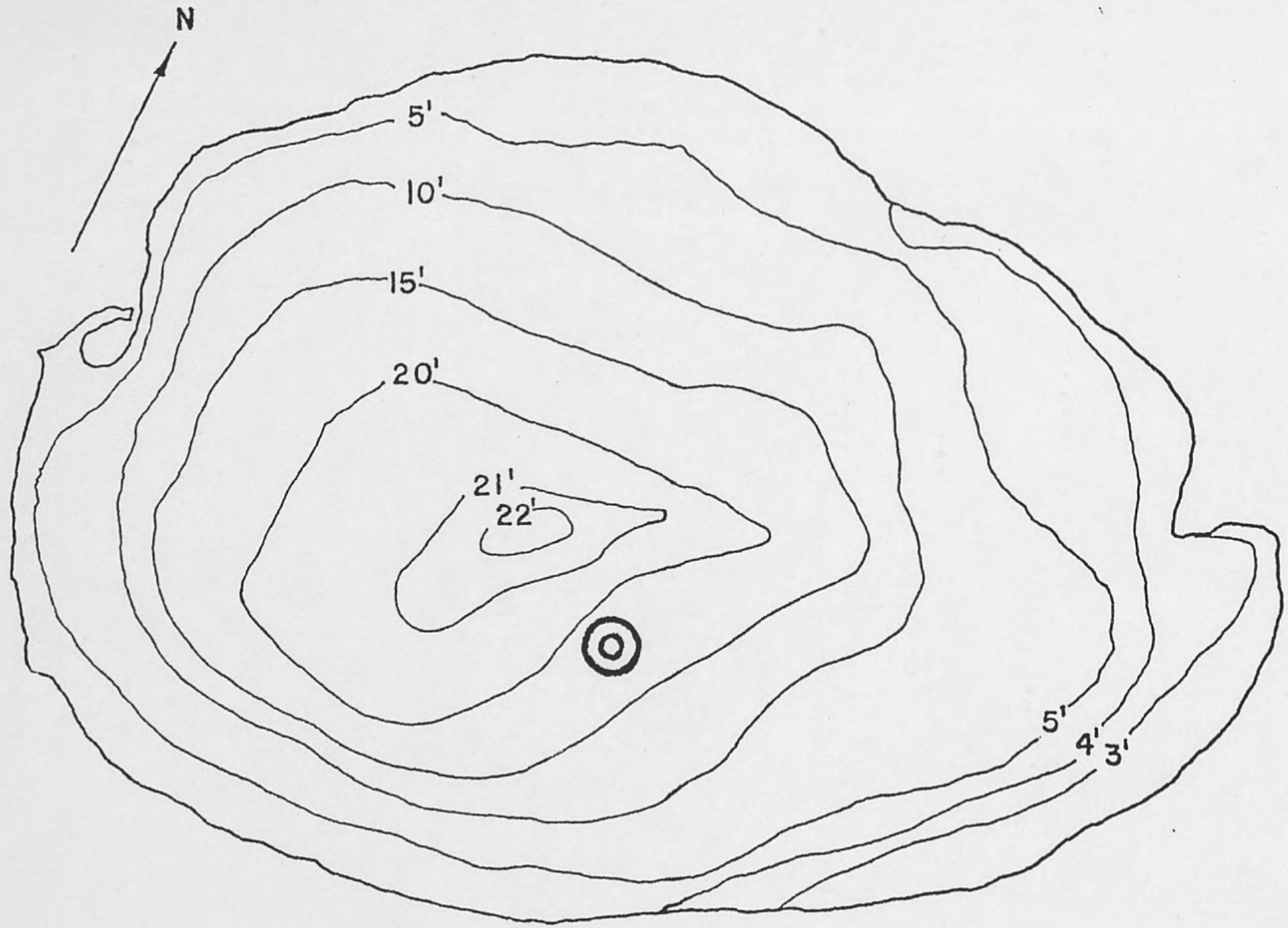


Fig. II-2. Water depth contours for Lake Eola.

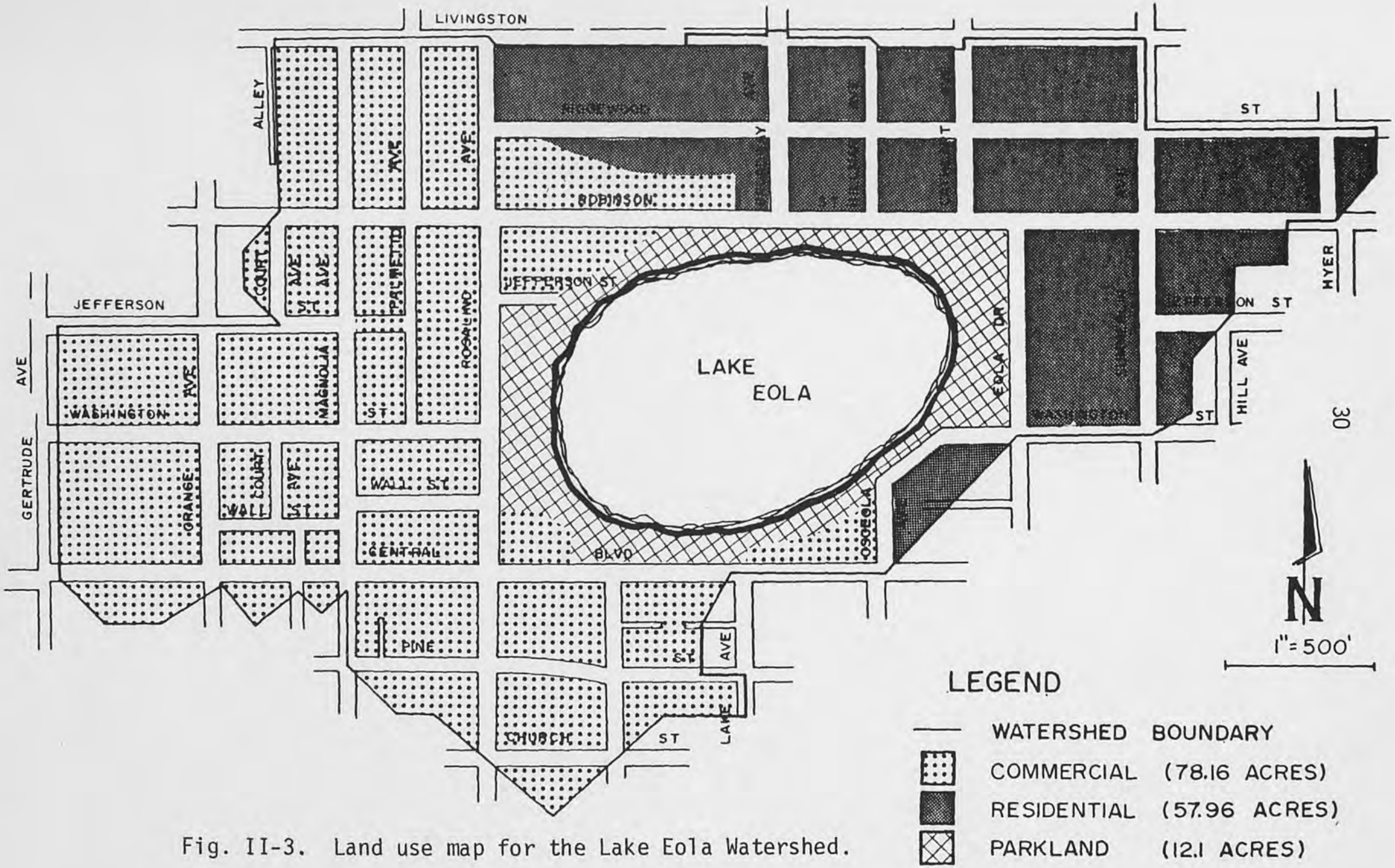


Fig. II-3. Land use map for the Lake Eola Watershed.

or gravels (S.C.S., 1975). Hence, open space areas in the Lake Eola watershed generate relatively little stormwater runoff. However, approximately 60 percent of the watershed consists of impervious surfaces such as streets, parking lots and buildings (Chancellor, 1975). Thus, despite favorable hydrologic soil qualities, the potential for runoff in the Lake Eola watershed is great due to the expanse of impervious surfaces.

Nearly 1.4×10^8 gallons of stormwater runoff are contributed to the lake annually. Wanielista et al. (1977) developed pollutant mass loadings for two sub-areas of the Lake Eola Watershed. Mass loadings from a 28 acre commercial area are presented in Table II-9; similar loadings for a 16.1 acre residential area are shown in Table II-10. Comparison of these tables reveals that the loadings for the commercial site excluding those for BOD, COD, and TOC, exceeded the loadings reported for the residential site.

Pollutant loadings such as those listed in Tables II-9 and II-10 have produced severe lake trophic state perturbations. The trophic state of Lake Eola has been predicted as eutrophic according to the trophic state models of Vollenweider, Dillon, and Larsen-Mercier (Marshall, 1980). Similar lake conditions in 1972 compelled city, county and state agencies to organize and implement a plan of lake restoration. The restoration activities carried out at that time are outlined below.

1. Expanded street sweeping service was provided in the Lake Eola watershed.

TABLE II-9

MASS LOADING FROM URBAN STORMWATER RUNOFF
FROM 28-ACRE COMMERCIAL AREA AT LAKE
EOLA DRAINAGE BASIN, LE1

Constituent	Estimated Mass (lb)		Average Mass Loading	
	0.8 mm storm on 5/5/75	18 mm storm on 5/12/75	kg/ha-yr	lb/in./sq mile
SS	14.61	103.82	338	3,380
BOD	7.14	10.12	50	540
COD	32.27	71.51	296	3,250
TOC	11.12	32.10	123	1,353
TKN-N	0.25	0.94	4	37.3
NO_3-N	0.11	2.15	6	70.7
OP-P	0.038	0.58	2.0	19.4
TP-P	0.045	1.17	3.5	38

SOURCE: Wanielista, Martin P.; Yousef A. Yousef; and Waldron M. McLellon. "Nonpoint Source Effects on Water Quality," Journal Water Pollution Control Federation 49 (March 1977): p. 447.

TABLE II-10

MASS LOADING DUE TO STORMWATER RUNOFF FROM
16.1 ACRE RESIDENTIAL AREA AT
LAKE EOLA DRAINAGE BASIN, LE2

Constituent	Estimated Mass (lb)		Average Mass Loading	
	356 mm storm on 6/1/75	5 mm storm on 6/2/75	kg/ha-yr	lb/in./sq mile
SS	6.70	11.60	195.00	2,140.0
BOD	4.10	2.90	74.60	818.4
COD	19.10	22.40	442.30	4,852.0
TOC	6.20	6.80	138.50	1,520.0
TKN-N	0.07	----	1.81	19.9
NO_3-N	----	0.12	2.17	23.8
OP-P	0.025	0.05	0.80	8.8
TP-P	0.12	0.09	2.24	24.5

SOURCE: Wanielista, Martin P.; Yousef A. Yousef; and Waldron M. McLellon. "Nonpoint Source Effects on Water Quality," Journal Water Pollution Control Federation 49 (March 1977): p. 448.

2. Inlet discharges were extended into the lake to a depth of 10 feet to alleviate problems associated with siltation.

3. Screening devices were installed in street drains to prevent debris from entering the lake.

4. The lake was drawn down to the 10 foot water depth contour; sediments were consolidated due to exposure.

5. The lake bottom was cleared of accumulated trash and junk.

6. Eighty-thousand (80,000) cubic yards of clean sand were used to establish a more aesthetic and stable bottom. The shoreline was contoured to permit the growth of rooted aquatic plants.

7. The lake was refilled with clean well water and stocked with fish.

8. A program of algacide applications was initiated.

CHAPTER III

PROCEDURE

In order to provide a valid composite stormwater sample for column study, it was necessary to obtain a series of discrete samples that were distributed over the duration of each runoff event. Sampling crews were dispatched regularly to the study area in anticipation of storm events. Hence, individuals were on-site to capture samples from the initial discharges of stormwater runoff produced by each of the events.

Stormwater Runoff Sampling

Seven column studies were performed on stormwater runoff collected at four separate sites within the Lake Eola watershed. The sampling sites were termed Lake Eola-North, School, Lake Eola-West and George Stuart. The latter two were situated in commercial areas, whereas, the former were located in residential areas. The contributing watershed area at each sampling point was 1.10, 5.72, 0.56 and 0.42 acres, respectively. The location of each sampling site is indicated on the map in Figure III-1.

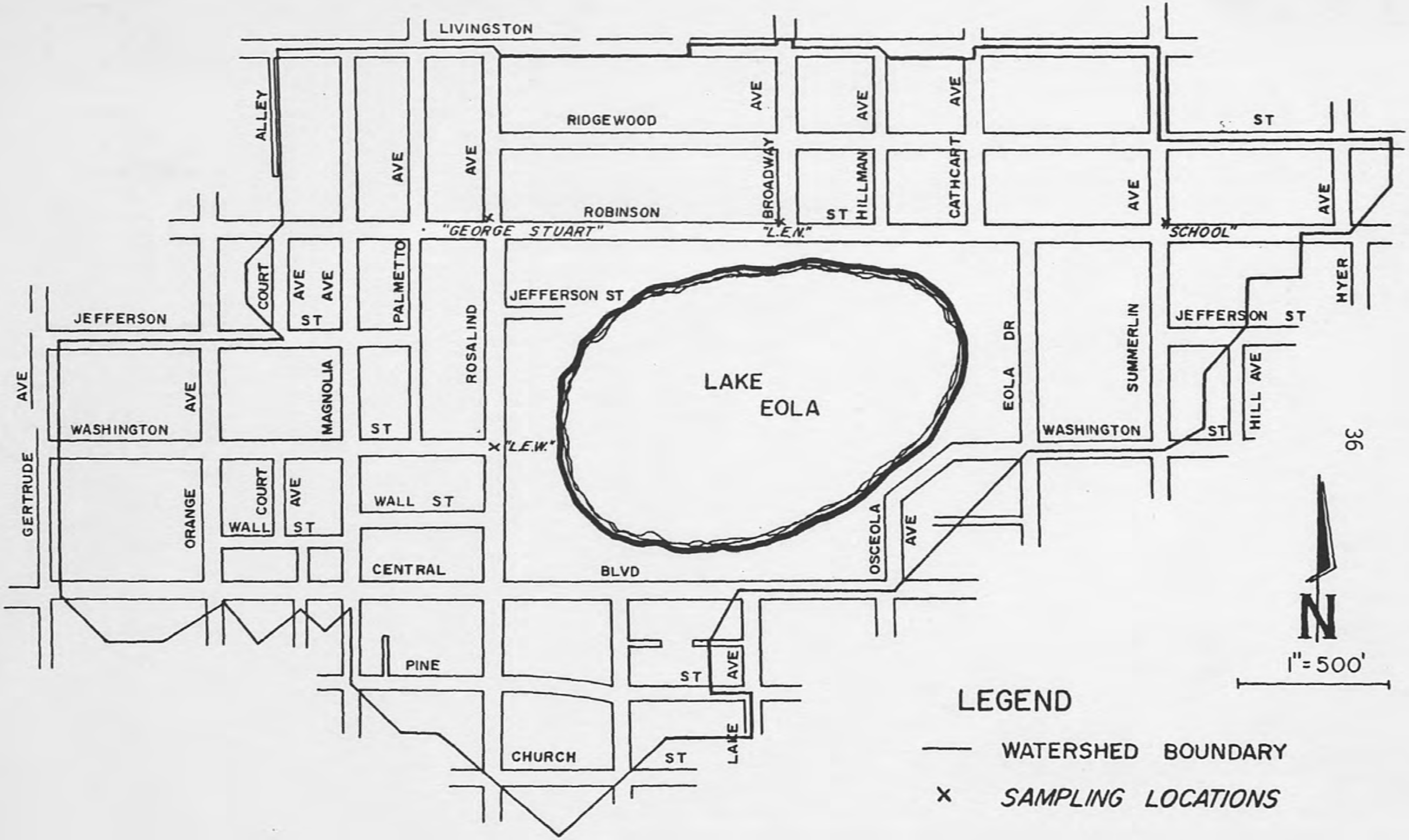


Fig. III-1. Location map of sampling sites within the Lake Eola watershed.

Sampling Procedure

Suitable containers for sample collection were obtained from local donut shops. Jelly and other pastry fillings are typically packed in four and five gallon plastic pails. These pails were equipped with handles which eased the sampling procedure and tight fitting lids which alleviated transportation difficulties.

With the exception of Lake Eola-West, all the sampling sites involved gutter inlets with catch basins. Removal of the manhole covers at each inlet structure provided access to the catch basin for sampling. The sampling procedure routinely involved lowering a bucket by hand and holding it beneath the inlet permitting stormwater to flow unimpeded into the container. As each sample was taken, the time was noted along with the duration of time required to fill the bucket. The approximate time rainfall began was also recorded for each storm event.

The Lake Eola-West site also involved a manhole. However, sampling conditions were considered hazardous and only one sampling was attempted. The remaining sites were sampled two times during the study period, that extended from April to July of 1979.

Field judgement was exercised in determining when a sample should be taken. In many cases, all the available sampling buckets, numbering between 20 and 24, were filled before the runoff event was complete. Hence, the contents of select buckets were discarded as required to extend sampling to the conclusion of the runoff event. The samples were transported immediately to the laboratory for the column study settling analysis.

Composite Column Study Sample

The initial task associated with the column study was to determine the fractional volume of each runoff sample to be used in filling the column. The time observations recorded by the sampling crews were used to establish the runoff hydrograph. The volume of the bucket, divided by the duration of time to fill, yielded the discharge rate pertaining to each sample. The rate of discharge accompanied by the sampling time provided the data necessary to produce the runoff hydrograph. Sampling and hydrograph data are presented for each storm event in Tables A-1 to A-7 in the Appendices.

Inspection of these Tables reveals the procedure used to determine the composite runoff sample of 122.3 liters that was required for each storm studied. The storm volume in gallons represented by each sample bucket was derived from the product of the flow in gallons per minute and the elapsed time interval between the sample of interest and the sample it preceded. The percentage of each runoff sample to be used was found by dividing the runoff volume represented by each bucket by the total stormwater runoff volume. This fraction was subsequently multiplied by the column volume in liters to determine the volume of each bucket to be used in the study. However, in a few isolated cases, the volume of runoff required of a bucket exceeded its capacity. Runoff volumes from adjacent samples were then used to make up the difference. The contents of the buckets were mechanically stirred to resuspend any settled material prior to sample proportioning and the subsequent filling of the column.

Column Apparatus

The settling column measured 6 feet in length and 1 foot in diameter. Sampling ports were arranged at various depths along the column of which only three were utilized during the studies. These were located at depths of 1.1 (port 1), 3.0 (port 3), and 4.5 (port 5) feet below the height of the initial height of the filled column. The column was mounted in an apparatus designed to uniformly mix the stormwater contained in the column simultaneously in the vertical plane perpendicular to the laboratory floor and also around its own centroidal axis. The watertight sealing unit occupied the top six inches of the column diminishing its effective length to 5.5 feet. Consequently, the volume of the sealed column was 122.3 liters.

Column Study Procedure

Once the column had been filled with the composite stormwater sample, the seal or cap was applied. During the sealing process entrapped air was forced out through a valve located on top of the cap. Once as much air as possible had been evacuated, the valve was closed and the dual axis rotation was initiated. The column was rotated for 5 minutes after which time the column was halted and locked into its upright position. The air valve was released and samples were withdrawn immediately and simultaneously from the three ports. Subsequent samples were withdrawn after 5, 10, 15, 30, 60 and 120 minutes of settling had elapsed.

Samples were collected in 500 milliliter glass erlenmeyer flasks that were coded to reflect port depth and sampling time. One hundred milliliters of each sample were transferred to a similarly coded flask to be used for the metals analysis. The pH of these samples was lowered to less than 2 with nitric acid.

The remaining sample volume of approximately 400 milliliters was treated with mercuric chloride for preservation purposes. The general water quality samples were sealed and placed into refrigerated storage at 4^{o} C. The metals samples were sealed and stored on the shelf at room temperature.

Water Quality Analysis

The general water quality parameters of interest were Total Suspended Solids (TSS), Volatile Suspended Solids (VSS), Nonvolatile Suspended Solids (NVSS), Total Organic Carbon (TOC), Chemical Oxygen Demand (COD), Ammonia Nitrogen (NH_3-N), Total Kjeldahl Nitrogen (TKN), and Total Phosphorus (TP). The metals analysis included Calcium (Ca), Cadmium (Cd), Copper (Cu), Chromium (Cr), Nickel (Ni), Magnesium (Mg), Zinc (Zn), Arsenic (As), Iron (Fe), and Lead (Pb). The settled stormwater samples were analyzed expiditiously to ensure the validity of the laboratory results. The analytical methods used to determine the parameters above are summarized in Table III-1. In most cases, experimental procedure followed Standard Methods (1976).

TABLE III-1

CHEMICAL ANALYSES METHODS FOR THE LAKE EOLA COLUMN STUDY

Parameter	Method	Reference
Residue		
Total Suspended Solids	Dry at 105° C and weigh	Standard Methods - 14th Ed.
Non-volatile Suspended Solids	Ignition at 550° C	APHA 1976
Volatile Suspended Solids	Difference	
Chemical Oxygen Demand	Dichromate digestion followed by spectrophotomatic determination of chromic ion	Oceanography International Corporation, 1978
TKN	Acid digestion followed by distillation and acidimetric filtration of ammonia	Standard Methods - 14th Ed. APHA 1976
NH_3	Filtration followed by phenate determination of ammonia	Standard Methods - 14th Ed. APHA 1976
TOC	Beckman Model 915A TOC Analyzer with Model 215B Infrared Analyzer	Standard Methods - 14th Ed. APHA 1976
Total Phosphorus	Persulfate digestion - ascorbic acid reduction of phosphomolybdic acid - absorbance measured at 880 nm	Standard Methods - 14th Ed. APHA 1976
Soluble reactive phosphorus	Filtration, ascorbic acid reduction of phosphomolybdic acid - absorbance measured at 880 nm	Standard Methods - 14th Ed. APHA 1976
Metals	Plasma emission spectrophotometry	SMI, 1978

CHAPTER IV

RESULTS

Seven runoff events were sampled during the period extending from the month of April through the month of July of 1979. The mean values associated with each event for the general water quality and metals parameters are summarized in Table IV-1. As shown in Table IV-1, the column studies associated with each storm event have been designated in chronological order as column studies 1 through 7. The mean value, the maximum and minimum value and the standard deviation for the storms considered collectively are also listed in Table IV-1. In addition, pertinent watershed, rainfall and runoff data are also presented.

The mean values listed in Table IV-1 were determined by averaging the initial (time = 0) concentrations found at each of the three sampling ports.

The quality of stormwater is extremely variable and is dependent on a variety of factors. Antecedent moisture conditions, for example, exert a major influence on stormwater quality. The initial storm that occurred on April 5, 1979 was preceded by nearly 30 days of dry weather. Consequently, a severe accumulation of pollutants occurred in the watershed. Accordingly, the quality of the stormwater reflected this condition and the highest values

TABLE IV-1

STORM CHARACTERISTICS AND STORMWATER QUALITY FOR ALL STORMS UTILIZED IN THE LAKE EOLA COLUMN STUDY

Storm	Average Data for Individual Storms (1979)							Data for All Storms			
Date	4/05	4/25	5/24	6/22	6/27	7/08	7/12	Mean	Max	Min	Std. Dev.
Column Study Number	1	2	3	4	5	6	7				
Location	School	G.S.	LEW	LEN	School	LEN	G.S.				
Drainage Area (acres)	5.12	0.42	0.56	1.10	5.12	1.10	0.42				
Duration (min)	184.00	103.00	121.10	29.40	59.50	21.50	131.90	92.90	184.0	21.50	
Runoff Volume (gal)	8595.00	420.40	1593.80	1030.60	1965.00	1223.30	3236.70	2580.70	8595.0	420.40	
Precipitation (in.)	10.16	0.06	0.42	0.07	0.10	0.11	0.33				
Peak Flow (gpm)	114.30	16.00	33.30	100.00	86.20	71.40	57.10	68.30	114.3	16.00	
Sample Percent	0.41	7.7	2.00	3.10	1.60	2.60	1.00	2.63	7.7	0.38	
Water Quality Parameters - Mean Values											
TSS (mg/l)	138.60	71.20	53.00	76.70	260.30	360.00	61.30	145.90	524.0	19.00	126.1
VSS (mg/l)	123.30	44.00	20.30	49.30	129.70	240.00	22.70	89.90	348.0	3.00	83.2
NSS (mg/l)	15.30	27.20	32.70	27.30	130.70	120.00	38.70	56.00	176.0	12.00	51.7
COD (mg/l)	-------	226.00	57.10	128.00	255.70	270.00	76.90	168.90	335.0	54.50	92.0
TKN (mg/l)	17.60	1.40	1.20	3.00	1.00	4.40	0.90	4.20	17.9	0.80	5.8
NH_3 (mg/l)	2.10	-------	0.30	0.90	0.10	0.20	0.20	0.50	2.8	0.00	0.7
TOC (mg/l)	520.00	61.00	19.90	29.50	29.00	-------	-------	139.90	540.0	16.80	206.8
TP (mg/l)	3.20	0.03	0.10	1.00	1.50	0.90	0.20	1.00	3.3	0.10	1.0
Metals - Mean Values											
Ca (mg/l)	83.60	62.00	26.70	34.00	67.00	21.00	31.30	46.50	125.0	5.00	29.1
As (ppb)	124.00	195.00	98.00	44.00	1135.00	34.00	68.00	256.00	1226.0	0.00	397.0
Cd (ppb)	18.00	14.00	52.00	44.00	28.00	74.00	11.00	34.00	154.0	4.00	39.0
Cu (ppb)	190.00	97.00	56.00	60.00	65.00	39.00	126.00	90.00	196.0	21.00	53.0
Cr (ppb)	51.00	64.00	21.00	25.00	31.00	15.00	29.00	33.00	66.0	14.00	16.0
Ni (ppb)	109.00	59.00	22.00	27.00	33.00	15.00	20.00	38.00	138.0	12.00	32.0
Mg (ppb)	6325.00	-------	406.00	899.00	2742.00	551.00	715.00	1391.00	6325.0	97.00	1574.0
Zn (ppb)	940.00	455.00	303.00	801.00	672.00	467.00	407.00	559.00	1050.0	81.00	247.0
Fe (ppb)	3328.00	1580.00	795.00	836.00	1597.00	1162.00	884.00	1455.00	3650.0	211.00	892.0
Pb (ppb)	1913.00	747.00	316.00	278.00	625.00	345.00	386.00	659.00	2240.0	29.00	572.0

for TKN, NH_3, TOC, TP, and the metals Ca, Cu, Ni, Mg, Zn, Fe and Pb were recorded for this storm. The sample taken at the Lake Eola-North site on 7/08/79 yielded the high values for TSS, VSS, COD, and Cd. The magnitude of the solids data was attributed to the presence of construction activity within the drainage area. The sample obtained at the school site on 6/27/79 produced an arsenic concentration over 4 times greater than the overall storm average of 256 ppm. An explanation for this extreme was not possible since no unusual activity in the drainage area was apparent. The maximum concentration measured for NVSS also occurred for the 6/27/79 storm. The chromium concentration associated with the 4/25/79 storm was the highest recorded during the sampling period.

The raw data generated by each column study are summarized by port and sampling time in Tables B-1 through B-14 in the Appendix section. These tables are arranged in terms of the general water quality parameters and the metals parameters.

Removal efficiencies were then calculated by port and sampling time for all the parameters investigated. This was done by taking the ratio of the initial values measured at each port and the difference in concentration that occurred during settling. The removal efficiencies associated with each column study are presented in Tables IV-2 through IV-19. Tables IV-2 through IV- 9 summarize general water quality parameter removal; while the remaining tables list metals removals. Inspection of these tables reveals that in many instances negative removals were exhibited. This occurrence was attributed to convection currents in the fluid that were apparently created by the spinning motion of the column. These currents typically dissipated in a few minutes. Nevertheless, their presence did modify the efficiencies exhibited by some of the constituents, especially those associated with the initial sampling times (5, 10 and 15 minutes).

The removal efficiencies by sampling port for each stormwater constituent are plotted as a function of time in Figure IV-1. Although these graphs are very general, they do illustrate the observed removal trends. The following discussion will address each parameter in detail.

Total Suspended Solids

Initially, it was thought that a majority of the suspended solids contained in the stormwater runoff would be of the discrete variety. However, the ensuing field sampling and column studies suggested that perhaps there were more flocculent particles in the stormwater than had originally been anticipated. Theoretically, plain sedimentation will only remove those particles with a specific gravity greater than that of water. Hence, flocculent particles were removed as they coagulated and grew in size.

The total suspended solids removal results are listed in Table IV-2. After two hours of settling, percent removals at port 1 ranged between -24.44 percent to 94.74 percent, with an average

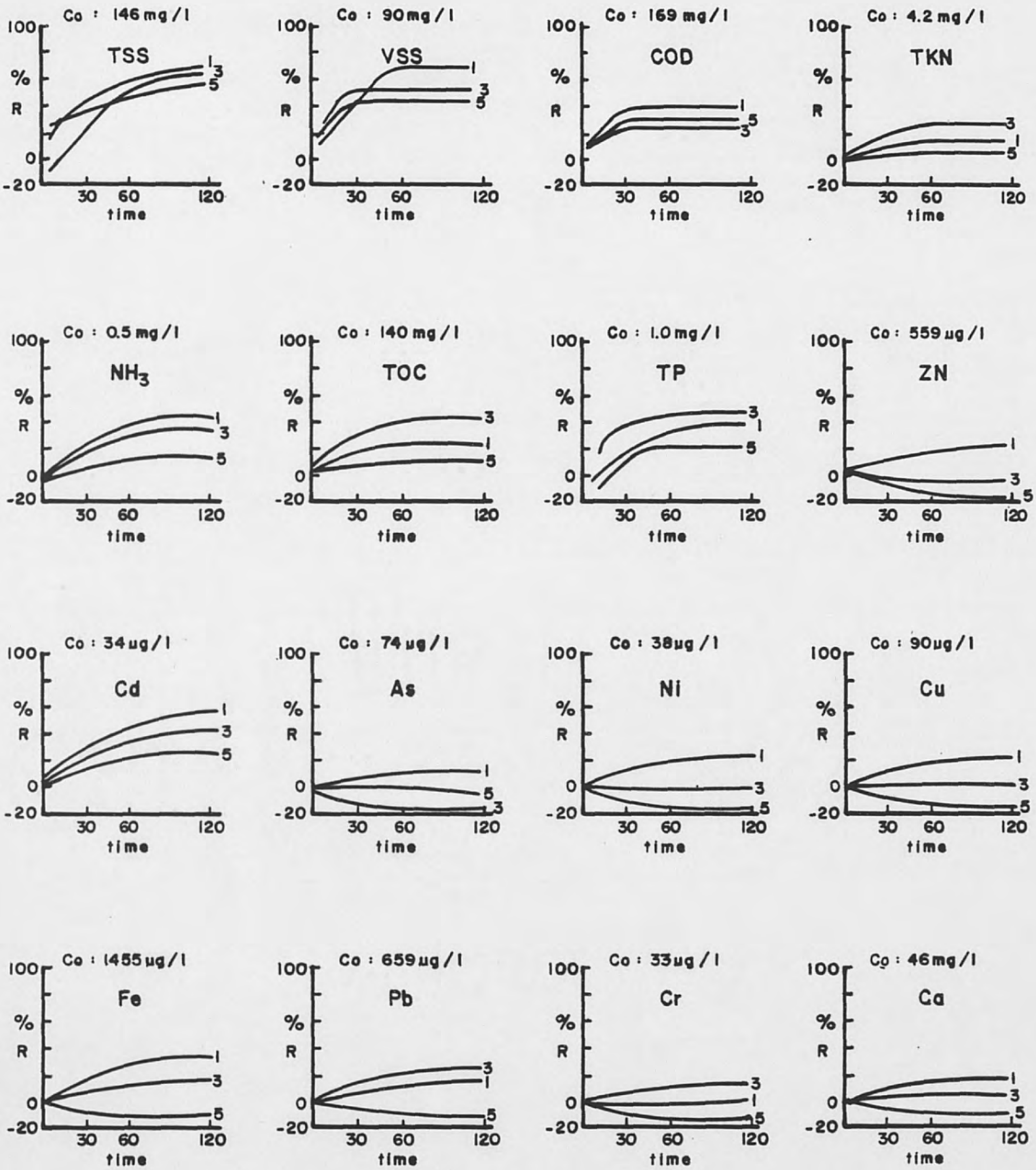


Fig. IV-1. Generalized representation of percent removal versus time for the various parameters investigated during the settling of Lake Eola stormwater.

TABLE IV-2

SUMMARY OF PERCENT TOTAL SUSPENDED SOLIDS REMOVAL AND AVERAGE REMOVAL FOR ALL SETTLING COLUMN STUDIES

Settling Time (Min.)	Column Study Number							Average Removal
	#1	#2	#3	#4	#5	#6	#7	
				PORT 1				
5	27.270	- 0.741	-226.320	8.000	26.250	64.780	30.769	- 9.99
10	-372.730	11.111	15.790	24.000	31.250	79.874	36.923	-24.83
15	31.170	6.667	- 89.470	28.000	65.625	84.906	49.231	25.16
30	11.690	33.333	-136.840	52.000	73.125	88.994	60.000	26.04
60	50.650	37.778	- 5.260	60.000	73.125	91.824	61.538	52.81
120	25.970	- 24.444	94.740	76.000	--	93.082	70.769	56.02
				PORT 3				
5	22.535	- 5.195	22.951	33.333	53.918	43.697	17.241	26.93
10	- 23.944	14.286	62.295	58.824	55.486	66.387	25.862	37.03
15	0.000	25.974	9.836	62.745	54.859	68.908	25.862	35.45
30	- 18.310	28.571	18.033	66.667	83.386	79.832	36.207	42.06
60	- 46.479	33.766	65.574	74.510	85.580	84.454	58.621	50.86
120	- 1.408	36.364	16.393	74.510	85.580	88.655	- 1.724	42.62
				PORT 5				
5	- 33.333	1.449	12.658	38.462	42.384	67.176	19.672	21.21
10	- 3.333	- 4.348	8.861	51.282	55.960	75.573	21.311	29.33
15	- 43.333	8.696	84.810	48.718	67.219	77.672	32.787	39.51
30	- 10.000	8.696	43.038	69.231	83.113	89.313	37.705	45.87
60	- 6.667	27.536	30.380	70.513	82.450	93.130	59.016	50.91
120	- 10.000	34.783	81.013	70.513	81.457	92.366	62.295	58.92

Note: 3 decimal place accuracy based on mathematical computation only

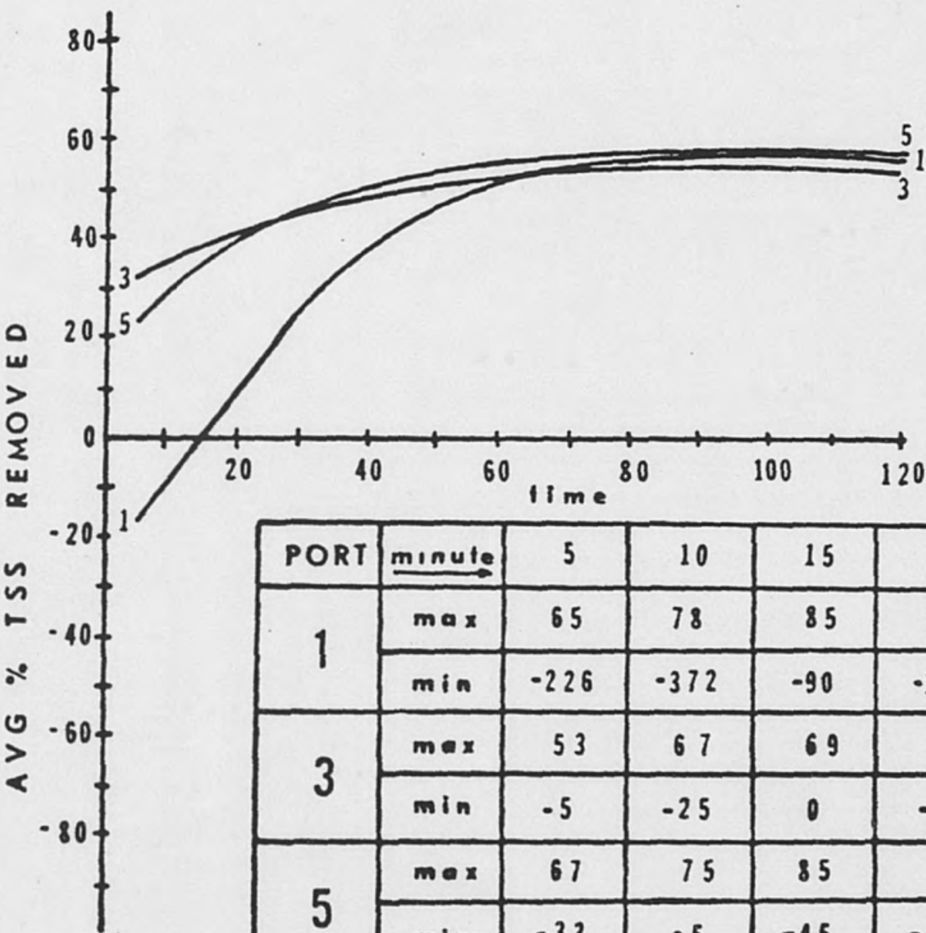
removal of 56.02 percent. The removals corresponding to port 3 ranged between -1.40 to 88.65 percent, with an average of 42.62 percent. Removals at port 5 fell into the range of -10.00 percent to 92.36 percent, with an average removal of 58.92 percent.

Column studies No. 5 and No. 6 displayed excellent total suspended solids removal. The removal occurred very rapidly for each of these studies. Furthermore, these two studies had the highest initial concentrations associated with them. This seems to suggest, that at least for column studies No. 5 and No. 6, a substantial fraction of the suspended solids were in the discrete form.

The average percent total suspended solids removal listed in Table IV-2 is shown graphically in Figure IV-2 for each port. Figure IV-2 shows that percent total suspended solids removal did not vary greatly with port depth.

Volatile Suspended Solids

Based on 7 column studies, volatile suspended solids made up 62 percent of the TSS. Table IV-3 indicates that a majority of the column studies resulted in significant removals of volatile suspended solids. Removal ranges at ports 1, 3 and 5, respectively, were 29.41 to 95.32 percent, 7.93 to 97.64 percent and -18.51 to 93.67 percent after two hours of subsidence. The average removals at ports 1, 3 and 5 were 58.53, 49.97 and 47.14 percent, respectively. Removal for the most part was complete after 1 hour of settling producing an average removal, based on 7 column studies, of 54.16 percent for all three ports.



PORT	minute	5	10	15	30	60	120
1	max	65	78	85	88	90	93
	min	-226	-372	-90	-136	-5	-30
3	max	53	67	69	85	80	70
	min	-5	-25	0	-19	-45	15
5	max	67	75	85	90	93	95
	min	-33	-5	-45	-12	-5	-10

Fig. IV-2. Average percent total suspended solids removed versus time for settled stormwater runoff from the Lake Eola watershed.

TABLE IV-3

SUMMARY OF PERCENT VOLATILE SUSPENDED SOLIDS REMOVAL AND AVERAGE REMOVAL FOR ALL SETTLING COLUMN STUDIES

Settling Time (Min.)	Column Study Number							Average Removal
	#1	#2	#3	#4	#5	#6	#7	
PORT 1								
5	25.000	17.391	-300.000	22.222	31.818	67.290	19.048	-16.75
10	-426.470	21.739	-433.000	22.222	38.636	82.243	28.571	-95.20
15	25.000	28.261	-233.000	44.444	71.591	87.850	47.619	10.20
30	12.500	45.652	0.000	55.556	73.864	91.121	47.619	46.62
60	39.710	52.174	100.000	55.556	69.318	93.458	38.095	64.04
120	29.410	39.130	66.670	77.778	--	95.327	42.857	58.53
PORT 3								
5	22.222	- 4.255	23.256	40.625	54.194	43.038	9.091	26.88
10	- 20.635	14.894	46.512	59.375	52.258	70.886	18.182	34.50
15	1.587	25.532	79.070	59.375	54.839	72.152	22.727	45.04
30	17.460	38.298	76.744	59.375	82.581	86.076	36.364	56.70
60	- 39.683	44.681	51.163	71.875	84.516	87.975	50.000	50.08
120	7.937	42.553	97.674	68.750	75.484	89.241	-31.818	49.97
PORT 5								
5	- 27.778	7.692	40.000	33.333	38.356	70.690	16.000	25.47
10	- 3.704	7.692	33.333	37.500	54.110	74.713	24.000	32.52
15	- 46.296	10.256	33.333	54.167	67.808	85.920	32.000	33.88
30	- 11.111	15.385	66.667	62.500	84.247	90.805	40.000	49.78
60	- 1.852	23.077	66.667	68.750	81.507	--	52.000	48.36
120	- 18.519	35.897	13.333	68.750	80.822	93.678	56.000	47.14

Note: 3 decimal place accuracy based on mathematical computation only

The average TSS and VSS removals exhibited after 60 minutes of settling were 51.5 percent and 57.16 percent, respectively. This means that of the average initial TSS concentration of 145.9 mg/l, only 51.5 percent was settleable. However, approximately 54.16 percent of the initial VSS concentration of 89.9 mg/l was settleable. Hence, approximately 65 percent of the settleable solids were volatile.

The average ratio of VSS to TSS was approximately 58 percent initially. One hour of settling produced only a minor reduction in this ratio to 56.5 percent. This implies that the remaining solids (NVSS) settled at the same rate as the VSS. This, in turn, implies that the NVSS, which would typically be of a discrete variety, behaved similarly to the VSS, which are usually found to be colloidal or of a non-discrete nature. This supports the earlier contention that a majority of the suspended particles were flocculent and not discrete.

Non-volatile Suspended Solids

Based on seven column studies, NVSS made up 38 percent of the TSS. Removals of NVSS are summarized in Table IV-4. There is a significant disparity between the average removals listed for 60 and 120 minutes at each of the sampling ports. This was likely due to the first 3 column studies that produced rather erratic results. The removals listed for all column studies at port 1 after 120 minutes of settling ranged between -179.07 and 100 percent with an

TABLE IV-4

SUMMARY OF PERCENT NON-VOLATILE SUSPENDED SOLIDS REMOVAL AND AVERAGE REMOVAL FOR ALL SETTLING COLUMN STUDIES

Settling Time (Min.)	Column Study Number							Average Removal
	#1	#2	#3	#4	#5	#6	#7	
				PORT 1				
5	44.444	- 39.530	-212.500	-28.571	19.444	59.615	36.364	-17.25
10	33.333	- 11.630	100.000	28.571	22.222	75.000	40.909	41.20
15	77.778	- 39.530	- 62.500	14.286	58.333	78.846	50.000	25.32
30	5.556	6.980	-162.500	42.857	72.222	84.615	65.909	16.52
60	100.000	6.980	- 25.000	71.429	77.778	88.462	72.727	56.05
120	0.000	-179.070	100.000	71.429	--	88.462	84.091	27.49
				PORT 3				
5	25.000	- 6.667	22.220	21.053	53.659	45.000	22.222	26.07
10	- 25.000	13.333	100.000	57.895	58.537	57.500	30.556	41.83
15	- 12.500	26.667	-155.560	68.421	54.878	62.500	27.778	10.31
30	-225.000	13.333	-122.220	78.947	84.146	67.500	36.111	- 9.60
60	-100.000	16.667	100.000	78.947	86.585	77.500	63.889	46.22
120	- 75.000	26.667	-177.780	84.211	95.122	87.500	16.667	8.20
				PORT 5				
5	- 83.333	- 6.667	6.250	46.667	46.154	60.227	22.222	13.07
10	0.000	- 20.000	3.125	73.333	57.692	77.273	19.444	30.12
15	- 16.667	6.667	96.875	40.000	66.667	61.364	33.333	41.18
30	0.000	0.000	37.500	80.000	82.051	86.364	36.111	46.00
60	- 50.000	33.333	21.875	73.333	83.333	--	63.889	37.63
120	66.667	33.333	96.875	73.333	82.051	89.773	66.667	72.67

Note: 3 decimal place accuracy based on mathematical computation only

average removal of 27.49 percent. Removals listed for port 1 after 60 minutes of settling were not as variable and ranged between -25.00 and 100.00 percent; the average was 56.05 percent. Port 2 removals ranged between -100.00 and 100.00 percent for 60 minutes of settling, and between -177.78 and 95.12 percent for 120 minutes of settling. Average removals were 46.22 percent and 8.20 percent for 60 and 120 minutes of settling, respectively. Removal at port 5 was probably the least variable. Sixty minutes of settling produced removals ranging from -50.00 to 83.33 percent with an average of 37.63 percent. After 120 minutes, removals were all positive and ranged from 33.33 to 96.87 percent; the average was 72.67 percent.

The ranges and averages of removals reported above may be deceiving. If only only studies 4 through 7 were considered in the analysis, an entirely different scenario of VSS removal would be possible.

Chemical Oxygen Demand

Removal percentages for each of the column studies are summarized in Table IV-5. Column study 6 exhibited the most complete treatment with removals approaching 80 percent for all three ports after 2 hours of sedimentation. However, in most cases, removal was near completion after 60 minutes. At port 1 COD removals ranged from 4.24 to 65.17 percent; the average was 36.04 percent. Very few negative removals were exhibited at port 1.

TABLE IV-5

SUMMARY OF PERCENT CHEMICAL OXYGEN DEMAND REMOVAL AND AVERAGE REMOVAL FOR ALL SETTLING COLUMN STUDIES

Settling Time (Min.)	Column Study Number							Average Removal
	#1	#2	#3	#4	#5	#6	#7	
				PORT 1				
5	--	-10.849	-50.000	7.813	54.925	66.207	12.500	13.43
10	--	- 6.604	0.000	7.813	55.522	58.621	- 4.167	18.53
15	--	-22.170	29.966	15.625	58.209	82.759	37.500	33.65
30	--	11.321	16.781	30.469	61.493	65.517	30.411	36.00
60	--	4.245	33.390	30.469	61.791	65.517	20.833	36.04
120	--	31.132	50.000	42.969	35.522	79.310	16.667	42.60
				PORT 3				
5	--	- 5.703	10.826	5.797	25.000	42.308	- 49.880	4.73
10	--	0.000	10.826	14.493	30.093	69.231	- 49.880	12.46
15	--	- 1.901	10.826	21.739	14.815	65.385	- 49.880	10.16
30	--	5.323	- 7.156	14.493	31.019	80.769	0.090	20.76
60	--	31.939	10.826	28.261	21.759	80.769	- 49.880	20.61
120	--	- 9.125	28.624	38.406	19.907	83.077	-166.430	- 0.92
				PORT 5				
5	--	-64.532	33.390	-11.864	20.833	11.538	0.000	- 1.77
10	--	-50.246	6.678	24.576	9.722	57.692	- 22.221	4.37
15	--	-23.645	-69.863	21.186	30.093	--	6.672	- 7.11
30	--	- 8.867	33.390	33.051	34.722	79.923	11.116	30.06
60	--	-22.660	16.781	41.525	35.185	79.231	15.561	27.60
120	--	-22.660	16.781	46.610	39.185	76.923	22.221	29.95

Note: 3 decimal place accuracy based on mathematical computation only

Removals at port 3 were not quite as high as those displayed by port 1. They ranged from -49.88 to 80.769 percent. The average removal produced by sedimentation at port 3 was 20.61 percent. Port 5 exhibited varied removal percentages that included a maximum of 79.231 percent and a minimum of -22.66 percent. The average COD removal at port 5 was 27.60 percent.

Based on 6 column studies and the removals shown by 3 sampling ports, approximately 28 percent of the COD contained in Lake Eola stormwater will be removed by 60 minutes of sedimentation.

Total Kjeldahl Nitrogen

The average initial concentration of TKN was 4.2 mg/l. The TKN removal percentages for each column study are listed in Table IV-6. Column study 6 continued its trend of efficient removal by displaying the highest removal percentages. As mentioned earlier, column study 6 had the highest initial concentration of TSS. Two-thirds of these solids were of a volatile form. Volatile suspended solids were removed in excess of 90 percent during this column study, which may explain the accompanying removal of TKN.

The highest average removal for each of the ports occurred after two hours of settling. Removal at port 1 had a range of -120.00 to 84.00 percent with an average of 18.63 percent. The range of removal at port 3 had a maximum of 74.074 percent and a minimum of -21.782 percent, the average was 23.34 percent. Port 5 removals were all quite low, ranging between -14.29 percent

TABLE IV-6

SUMMARY OF PERCENT TOTAL KJELDAHL NITROGEN REMOVAL AND AVERAGE REMOVAL FOR ALL SETTLING COLUMN STUDIES

Settling Time (Min.)	Column Study Number							Average Removal
	#1	#2	#3	#4	#5	#6	#7	
PORT 1								
5	- 3.049	8.333	30.357	31.378	-29.487	50.667	33.330	17.31
10	-39.773	41.667	- 9.821	40.051	0.000	64.000	20.000	16.59
15	- 6.818	25.000	9.821	57.143	-43.590	66.667	40.000	21.17
30	17.614	--	19.643	31.378	-57.692	80.000	40.000	21.82
60	- 1.705	- 16.667	50.000	48.469	-57.692	88.000	20.000	18.63
120	-13.068	25.000	-80.357	42.857	-87.179	84.000	-120.000	-21.25
PORT 3								
5	- 6.145	20.000	0.000	- 3.361	-44.554	15.741	16.667	- 0.24
10	-11.173	- 10.000	19.643	- 8.403	0.000	17.901	0.000	1.14
15	-17.318	40.000	80.357	20.168	-44.554	43.827	0.000	17.50
30	7.821	70.000	19.643	-13.025	-32.673	76.235	16.667	20.67
60	7.821	30.000	65.179	24.790	-21.782	74.074	- 16.667	23.34
120	- 7.821	0.000	-19.643	5.882	-21.782	74.074	58.333	12.72
PORT 5								
5	- 8.046	- 28.570	8.219	- 8.527	- 9.821	37.879	- 9.091	- 2.57
10	--	0.000	0.000	0.000	9.821	53.030	0.000	10.48
15	- 1.149	0.000	8.219	13.178	0.000	68.182	0.000	12.63
30	- 2.874	-100.000	23.288	3.876	-19.643	75.758	18.182	- 0.20
60	3.448	- 14.290	-15.068	0.000	- 9.821	80.303	9.091	7.67
120	0.000	14.290	30.822	0.000	-19.643	84.848	0.000	15.76

Note: 3 decimal place accuracy based on mathematical computation only

and 80.303 percent. The average removal was 7.67 percent. An additional 60 minutes of settling improved the average removal to 15.76 percent.

Overall, TKN removal was not favorable. The results were very erratic and contained many negative values. The average TKN removal after 60 minutes of sedimentation was only 16.55 percent. That percentage is based on 7 column studies and the removal data gathered from all three ports.

Ammonia Nitrogen

Ammonia nitrogen removal essentially followed the removal trends demonstrated by total kjeldahl nitrogen. The average initial concentration of NH_3-N was 0.5 mg/l. The calculated removal percentages for each of the column studies are listed in Table IV-7. The removal percentages fluctuated greatly, with port one displaying the most consistency. Maximum removal efficiency was achieved for each port after 60 minutes of settling. The removal range at port 1 was -38.46 percent to 78.603 percent; the average was 37.35 percent. The lowest removal recorded for port 3 was 0.00 percent; the highest was 100.00 percent. The average removal for port 3 was 34.39 percent. Port 5 displayed somewhat poorer removals. The range at port 5 was -17.64 to 52.06 percent with the average being 13.03 percent.

Based on the average removals shown in Table IV-7 for each port, a 28 percent reduction in ammonia nitrogen can be anticipated from Lake Eola stormwater due to one hour of sedimentation.

TABLE IV-7

SUMMARY OF PERCENT AMMONIA NITROGEN REMOVAL AND AVERAGE REMOVAL FOR ALL SETTLING COLUMN STUDIES

Settling Time (Min.)	Column Study Number							Average Removal
	#1	#2	#3	#4	#5	#6	#7	
PORT 1								
5	50.000	--	0.000	12.121	23.077	6.250	23.581	35.84
10	39.286	--	100.000	32.323	7.692	31.250	44.105	25.78
15	67.857	--	0.000	32.323	7.692	6.250	37.118	25.21
30	50.000	--	0.000	6.061	7.692	18.750	44.105	21.10
60	39.286	--	67.647	32.323	0.000	6.250	78.603	37.35
120	67.857	--	35.294	46.465	-38.462	37.500	78.603	37.88
PORT 3								
5	0.000	--	- 54.545	11.842	-15.385	- 6.667	37.255	- 4.58
10	47.059	--	0.000	11.842	0.000	13.333	26.797	16.51
15	17.647	--	0.000	7.895	0.000	0.000	37.255	10.47
30	0.000	--	- 54.545	14.474	7.692	0.000	5.882	- 4.41
60	0.000	--	100.000	18.421	7.692	26.667	53.595	34.39
120	17.647	--	0.000	11.842	23.077	- 6.667	26.797	12.12
PORT 5								
5	17.647	--	-136.360	14.634	0.000	13.333	33.884	- 9.48
10	0.000	--	-104.540	14.634	0.000	0.000	-19.008	-18.15
15	35.294	--	-104.540	10.976	18.750	- 6.667	7.438	- 6.46
30	64.706	--	- 54.540	7.317	6.250	0.000	-19.008	0.79
60	-17.647	--	0.000	31.707	18.750	- 6.667	52.066	13.03
120	35.294	--	- 54.540	18.293	18.750	0.000	72.727	15.09

Note: 3 decimal place accuracy based on mathematical computations only

Total Organic Carbon

The average initial concentration of TOC contained in the stormwater for all column studies was 139.9 mg/l. Column study 1 had an initial average TOC concentration of 520 mg/l; which exceeded the next highest column study by over 8 fold. If column study 1 is not considered in the computation of the average TOC concentration, it diminishes the value to 34.85 mg/l.

TOC removal was extremely varied at each port. Port 5 exhibited the weakest removal; whereas, port 3 provided significant and consistent removal. As for other constituents, sedimentation times in excess of 60 minutes produced no appreciable improvement. Port 1 removal percentages ranged from 11.32 to 38.67 percent, with an average value of 23.47 percent. The range at port 3 was 2.36 to 52.02 percent which produced an average of 34.67 percent. The maximum removal displayed by port 5 was 28.30 percent; the minimum was -19.04 percent. The average removal for 60 minutes of quiescent settling at port 5 was only 1.89 percent.

Referring to Table IV-8, it is apparent that TOC does not experience appreciable removal by sedimentation. Based on the averages shown, only about 20 percent of the TOC was settleable after 60 minutes.

Total Phosphorus

The average initial total phosphorus concentration was 1.0 mg/l. Table IV-9 summarizes the TP removal behavior displayed by

TABLE IV-8

SUMMARY OF PERCENT TOTAL ORGANIC CARBON REMOVAL AND AVERAGE REMOVAL FOR ALL SETTLING COLUMN STUDIES

Settling Time (Min.)	Column Study Number							Average Removal
	#1	#2	#3	#4	#5	#6	#7	
PORT 1								
5	- 1.748	13.208	--	-13.778	21.120	--	--	4.70
10	3.689	13.208	--	-23.556	29.771	--	--	5.78
15	-15.728	-24.528	--	12.000	25.445	--	--	- 0.70
30	20.000	3.774	--	3.111	27.990	--	--	13.72
60	20.777	11.321	--	23.111	38.677	--	--	23.47
120	29.709	26.642	--	-11.111	38.168	--	--	19.85
PORT 3								
5	- 1.782	22.078	3.030	46.662	0.323	--	--	14.05
10	- 1.188	16.883	--	51.126	- 6.452	--	--	15.09
15	-11.683	10.390	46.970	44.820	-11.290	--	--	15.84
30	17.030	12.987	43.434	46.396	29.677	--	--	29.90
60	2.366	44.156	40.909	52.027	32.903	--	--	34.67
120	22.574	0.000	44.444	52.027	43.871	--	--	32.58
PORT 5								
5	8.148	-35.849	17.000	-10.698	-39.286	--	--	-12.13
10	13.148	-43.396	20.000	2.791	-63.095	--	--	14.11
15	17.407	-24.528	12.000	-23.721	-56.548	--	--	-15.08
30	27.407	0.000	6.000	-28.837	-36.310	--	--	- 6.35
60	16.667	28.302	- 3.500	-13.023	-19.048	--	--	1.89
120	25.000	-13.208	49.500	4.186	30.952	--	--	19.29

Note: 3 decimal place accuracy based on mathematical computation only

TABLE IV-9

SUMMARY OF PERCENT TOTAL PHOSPHORUS REMOVAL AND AVERAGE REMOVAL FOR ALL SETTLING COLUMN STUDIES

Settling Time (Min.)	Column Study Number							Average Removal
	#1	#2	#3	#4	#5	#6	#7	
				PORT 1				
5	36.364	- 3.846	5.882	17.172	6.338	6.625	35.484	14.86
10	15.152	3.846	58.824	28.283	21.831	17.000	33.548	25.50
15	42.424	11.538	17.647	23.232	36.620	24.500	50.323	29.47
30	39.394	26.923	17.647	20.202	42.254	40.875	50.323	33.95
60	42.424	23.077	- 17.647	15.152	44.366	46.875	52.258	29.50
120	42.424	19.231	58.824	29.293	45.070	53.500	59.355	43.96
				PORT 3				
5	15.152	- 3.030	-133.330	8.696	19.412	6.340	4.636	-11/73
10	15.152	9.091	-533.330	8.696	23.529	8.493	29.139	-62.75
15	33.333	9.091	- 8.330	15.217	16.471	12.799	-54.305	3.47
30	36.364	45.452	--	9.783	41.765	32.057	-63.576	16.97
60	42.424	24.242	- 91.670	6.522	48.235	33.493	-54.305	1.28
120	24.242	30.303	58.330	6.522	49.412	41.268	-38.411	24.52
				PORT 5				
5	-13.793	-18.750	- 53.846	29.703	- 2.778	8.768	31.788	- 2.70
10	37.931	- 9.375	- 53.846	6.931	4.167	22.266	11.258	2.76
15	24.138	3.125	15.385	41.584	- 2.778	29.360	31.788	20.37
30	27.586	34.370	- 92.308	19.802	33.333	33.399	24.503	11.53
60	24.138	31.250	- 7.692	18.812	36.111	41.084	27.152	24.41
120	58.621	21.875	61.538	19.802	34.028	44.039	44.371	40.61

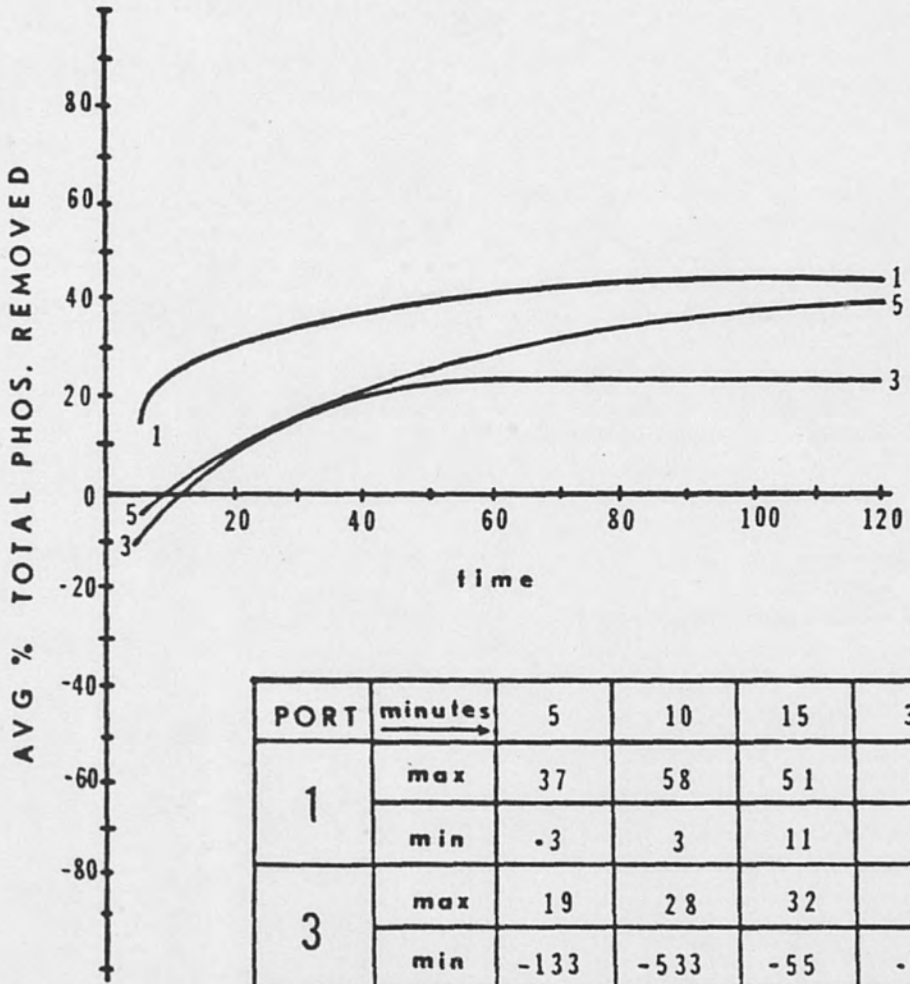
Note: 3 decimal place accuracy based on mathematical computation only

each column study. Collectively, the column studies exhibited a general trend of increased removal with time. Two hours of sedimentation were required to attain the ultimate removal efficiency. The relationship between total phosphorus removal and time is shown in Figure IV-3.

The range of removal at port 1, after 120 minutes of settling, was 19.23 to 59.3 percent. The average removal was 43.96 percent. Port 3 had a removal range from -38.411 percent to 49.412 percent. However, due to the negative removal recorded for column study 7, the average removal after two hours was considerably lower at 24.52 percent. Port 5 demonstrated moderately consistent removal of TP. The range of removal extended from 19.802 percent to 61.53 percent with an average removal of 40.61 percent.

Two hours of sedimentation produced rather significant removal of total phosphorus. Based on the averages shown in Table IV-9, approximately 36 percent of the total phosphorus contained in Lake Eola stormwater was removed after 2 hours of settling.

Previous studies of Lake Eola stormwater runoff indicate that total phosphorus is equally distributed among the dissolved and suspended form (Taylor). Therefore, it is evident that 2 hours of settling produced a 72% reduction in the available particulate phosphorus.



PORT	minutes →	5	10	15	30	60	120
1	max	37	58	51	51	53	60
	min	-3	3	11	18	-18	18
3	max	19	28	32	45	47	55
	min	-133	-533	-55	-65	-90	-38
5	max	31	38	42	35	41	60
	min	-55	-55	-3	-90	-8	-20

Fig. IV-3. Average percent total phosphorus removed versus time for settled stormwater runoff from the Lake Eola watershed.

Heavy Metals

The removal trends exhibited by the metals are graphically presented in Figure IV-1. Tables IV-10 through IV-19 summarize the removal shown by each constituent. These tables are arranged in the same manner as those for the general water quality parameters. Inspection of the tables and Figure IV-1 indicates that heavy metal removal was quite variable. In some instances, negative removals were firmly established.

Zinc removal fluctuated greatly. Consequently, negative values dominate the average removals listed in Table IV-10. The only consistent removal was displayed by column study 3. The results improved for cadmium which exhibited consistently more positive removal efficiencies (see Table IV-11). Column study 6, which had the highest initial concentration of cadmium at 74 ppb, also showed the most efficient removal. Approximately 70, 93 and 48 percent of the cadmium present was removed at ports 1, 3, and 5, respectively, after 60 minutes of subsidence.

Arsenic removal fluctuated greatly with column study 2 producing some negative removals of rather high magnitude. The results of column study 2 coupled with the negative removals interspersed throughout the remaining studies, produced negative values for the majority of the entries in the average removal column of Table IV-12. However, column studies 1, 5 and 6 demonstrated a trend towards increased removal with time.

TABLE IV-10

SUMMARY OF PERCENT ZINC REMOVAL AND
AVERAGE REMOVAL FOR ALL SETTLING COLUMN STUDIES

Settling Time (Min.)	Column Study Number #1	#2	#3	#4	#5	#6	#7	Average Removal
PORT 1								
5	--	-18.863	--	60.391	61.210	-342.090	- 4.520	- 48.733
10	20.635	21.705	38.072	42.910	- 4.350	53.510	20.720	27.598
15	17.460	6.202	15.422	26.773	-188.210	63.780	29.750	5.884
30	25.926	40.052	55.663	- 0.122	63.590	37.520	24.100	35.257
60	20.635	14.212	11.807	- 29.584	-106.070	42.410	11.300	- 5.040
120	--	59.432	34.458	57.946	-260.420	46.000	-130.510	- 32.181
PORT 3								
5	--	38.333	66.908	56.190	55.970	-885.330	- 26.790	-115.785
10	--	22.593	1.449	26.857	43.770	47.920	-317.090	- 29.084
15	--	32.222	- 43.720	43.810	39.870	40.590	- 73.720	6.507
30	--	34.259	2.899	- 7.619	-100.780	41.560	33.160	- 12.752
60	--	63.519	7.005	15.810	-154.800	7.820	5.100	- 9.527
120	--	56.111	31.159	64.667	- 97.660	47.920	- 68.620	5.595
PORT 5								
5	- 4.278	-33.485	-622.220	- 33.950	-118.480	- 45.789	-264.090	-160.329
10	16.043	1.139	-509.880	31.530	- 55.240	- 2.368	- 20.470	- 77.034
15	12.299	23.007	-640.740	-101.490	18.070	11.053	- 60.470	-105.506
30	22.460	23.918	-386.420	19.030	- 41.480	- 22.632	-185.230	- 81.479
60	19.251	18.451	- 93.830	99.100	12.530	48.158	-319.460	- 30.828
120	14.973	40.091	-197.530	11.010	-191.990	30.263	-190.270	- 69.065

Note: 3 decimal place accuracy based on mathematical computation only

TABLE IV-11

SUMMARY OF PERCENT CADMIUM REMOVAL AND
AVERAGE REMOVAL FOR ALL SETTLING COLUMN STUDIES

Settling Time (Min.)	Column Study Number							Average Removal
	#1	#2	#3	#4	#5	#6	#7	
				PORT 1				
5	-25.000	37.500	--	73.973	71.698	43.478	44.444	41.015
10	75.000	-500.000	73.984	78.082	73.585	76.087	11.111	-16.021
15	8.333	- 1.270	86.179	73.973	71.698	71.739	44.444	50.727
30	66.667	-250.000	45.528	75.342	81.132	60.870	11.111	12.950
60	- 8.333	75.000	87.805	79.452	86.792	69.565	22.222	58.929
120	-41.667	-200.000	81.301	79.452	-45.283	73.913	0.000	- 7.469
				PORT 3				
5	42.105	- 91.670	50.000	71.795	52.174	90.260	8.330	31.857
10	52.632	- 41.670	60.000	66.667	56.522	91.558	50.000	47.958
15	47.368	- 62.500	56.667	74.359	52.174	90.909	25.000	40.568
30	84.211	- 8.330	76.667	66.667	69.565	90.909	50.000	61.383
60	57.895	-100.000	43.333	71.795	69.565	92.857	25.000	37.206
120	42.105	- 79.170	46.667	74.359	69.565	89.610	-150.000	13.305
				PORT 5				
5	34.783	-310.000	-400.000	47.368	-28.571	61.905	50.000	-77.787
10	60.870	-330.000	-300.000	47.368	-71.429	71.429	8.333	-73.347
15	73.913	-220.000	- 50.000	31.579	-28.571	61.905	0.000	-18.739
30	52.174	-140.000	0.000	36.842	0.000	28.571	25.000	0.369
60	30.435	-260.000	- 1.250	42.105	28.571	47.619	25.000	-12.502
120	17.391	-160.000	-225.000	42.105	-85.714	52.381	50.000	-44.119

Note: 3 decimal place accuracy based on mathematical computation only

TABLE IV-12

SUMMARY OF PERCENT ARSENIC REMOVAL AND
AVERAGE REMOVAL FOR ALL SETTLING COLUMN STUDIES

Settling Time (Min.)	Column Study Number							Average Removal
	#1	#2	#3	#4	#5	#6	#7	
				PORT 1				
5	20.000	0.000	--	55.422	10.196	35.714	- 77.778	7.259
10	-118.180	-356.570	-1213.300	10.843	11.093	- 14.286	- 72.222	-250.379
15	3.640	-598.290	50.700	100.00	9.380	100.000	80.556	- 36.292
30	89.090	-220.000	- 1.200	84.337	39.233	100.000	- 51.389	5.718
60	73.640	- 34.860	88.000	100.00	49.837	100.000	100.000	68.088
120	--	-143.430	--	73.494	39.233	- 64.286	- 68.056	- 32.608
				PORT 3				
5	--	-332.510	--	4.000	3.675	--	--	-108.280
10	--	-292.020	--	96.000	11.111	--	--	- 61.638
15	--	-260.120	--	38.000	-10.061	--	--	- 77.394
30	--	- 74.230	--	64.000	13.823	--	--	1.970
60	--	-403.070	--	- 28.000	26.947	--	--	-134.706
120	--	-353.990	--	- 76.000	33.946	--	--	-132.014
				PORT 5				
5	35.036	-202.830	- 12.500	--	-51.844	- 2.667	- 1.527	- 39.396
10	67.153	-157.080	--	--	- 9.372	13.333	- 22.137	- 21.621
15	67.883	- 74.900	- 53.330	--	-21.546	10.667	- 56.489	- 21.286
30	87.591	- 52.230	90.830	--	26.087	82.667	- 6.870	38.013
60	56.934	-110.530	- 495.830	--	37.681	13.333	- 44.275	- 90.447
120	45.985	- 61.940	--	--	26.121	34.667	- 7.634	7.239

Note: 3 decimal place accuracy based on mathematical computation only

The average removals listed in Table IV-13 for nickel are almost entirely negative. Port 1 exhibited a positive removal trend for column studies 1, 4 and 5. Port 3 only displayed positive removal for column study 4 and port 5 demonstrated positive removal for column study 1. The removal efficiencies indicate that plain sedimentation is not adequate treatment for the removal of nickel from Lake Eola Stormwater.

Copper removal was varied among the column studies with column study 1 displaying the only consistent positive removal. The average removals for ports 1, 3 and 5 were 29.59, 5.54 and -90.79 percent after 60 minutes of sedimentation (see Table IV-14).

Magnesium removals for each column study are summarized in Table IV-15. Column studies 5 and 6 demonstrated positive removal trends; however, the values listed in the average removal column do not exceed 7 percent. Thus, it appears that the magnesium that was contained in Lake Eola stormwater was not amenable to treatment by plain sedimentation.

Iron maintained the variable removal behavior that was seemingly characteristic of the metals contained in Lake Eola stormwater runoff. Column study 1 displayed significant removal with an average removal efficiency of 37 percent for each port after 2 hours of settling. The remaining column studies lacked consistent positive removal for each port. Typically, treatment at port 5 was ineffective; this is reflected in the average removal column for port 5, which is entirely occupied by negative values. Ports 1 and 3

TABLE IV-13

SUMMARY OF PERCENT NICKEL REMOVAL AND
AVERAGE REMOVAL FOR ALL SETTLING COLUMN STUDIES

Settling Time (Min.)	Column Study Number							Average Removal
	#1	#2	#3	#4	#5	#6	#7	
				PORT 1				
5	--	- 50.820	--	48.718	68.750	-173.330	- 42.860	- 29.908
10	51.449	- 40.980	-790.320	30.769	- 68.750	26.670	- 14.290	-115.065
15	39.855	-137.700	- 6.450	- 12.821	26.563	20.000	- 28.570	- 14.161
30	50.725	8.200	-103.230	20.513	64.063	- 26.670	- 21.430	- 1.117
60	61.594	24.590	- 12.900	53.846	53.125	- 6.670	0.000	24.797
120	--	26.230	--	61.538	42.188	13.330	-257.140	- 22.770
				PORT 3				
5	--	- 12.500	--	13.040	- 21.050	-782.350	0.000	-160.572
10	--	- 19.643	--	-156.520	- 5.260	29.410	28.571	- 24.689
15	--	- 7.143	--	13.040	- 52.630	17.650	- 33.333	- 12.483
30	--	- 3.571	--	17.390	- 57.890	- 94.120	0.000	- 27.638
60	--	- 16.071	--	17.390	-305.260	- 29.410	4.762	- 65.718
120	--	1.786	--	17.390	-142.100	- 17.650	- 9.524	- 30.019
				PORT 5				
5	8.861	- 16.667	-516.670	5.000	-100.000	- 7.140	16.000	- 87.230
10	20.253	- 21.667	--	0.000	-247.000	0.000	8.000	- 40.078
15	5.063	6.667	-241.670	- 40.000	-129.410	- 71.430	- 4.000	- 67.825
30	31.646	- 26.667	-225.000	- 65.000	- 52.940	-692.860	- 40.000	-152.974
60	22.785	- 5.000	-550.000	- 25.000	- 47.060	- 14.290	- 8.000	- 89.508
120	20.253	8.333	--	- 70.000	-100.000	21.430	4.000	- 19.330

Note: 3 decimal place accuracy based on mathematical computation only

TABLE IV-14

SUMMARY OF PERCENT COPPER REMOVAL AND
AVERAGE REMOVAL FOR ALL SETTLING COLUMN STUDIES

Settling Time (Min.)	Column Study Number							Average Removal
	#1	#2	#3	#4	#5	#6	#7	
				PORT 1				
5	23.980	12.610	--	5.882	69.231	- 2.381	15.152	20.746
10	14.286	- 54.050	0.000	- 5.882	55.556	14.286	17.424	5.945
15	34.694	-211.710	36.364	-11.765	70.940	16.667	21.970	- 6.120
30	21.429	- 33.330	- 96.970	-13.235	61.538	14.286	27.273	- 2.716
60	28.571	18.920	36.364	32.353	45.299	21.429	24.242	29.596
120	25.000	- 10.810	- 13.636	29.412	56.410	14.286	27.273	18.276
				PORT 3				
5	22.995	- 74.468	13.750	8.621	-48.178	-53.846	- 4.032	-19.385
10	28.342	- 89.362	46.250	-24.138	- 7.692	15.385	16.129	- 2.155
15	4.813	- 65.957	43.750	15.517	0.000	-10.256	11.290	- 0.120
30	13.904	- 53.191	23.750	3.448	- 7.692	2.564	12.097	- 0.731
60	24.599	- 56.383	38.750	6.897	5.128	7.692	12.097	5.540
120	12.834	- 54.255	47.500	3.448	2.564	- 7.692	-24.194	- 2.827
				PORT 5				
5	6.915	-106.900	-166.670	3.636	-60.526	5.556	6.557	-44.489
10	17.021	-111.490	-200.000	12.727	-65.789	11.111	7.377	-47.006
15	3.191	- 82.760	-147.620	- 7.273	-36.842	2.778	7.377	-37.306
30	30.851	- 87.360	-147.620	3.636	-13.158	22.222	4.098	-26.760
60	-18.085	- 85.060	-485.710	12.727	-76.316	11.111	5.738	-90.799
120	27.128	- 65.520	-204.760	5.455	-31.579	33.333	- 5.738	-34.525

Note: 3 decimal place accuracy based on mathematical computations only

TABLE IV-15

SUMMARY OF PERCENT MAGNESIUM REMOVAL AND
AVERAGE REMOVAL FOR ALL SETTLING COLUMN STUDIES

Settling Time (Min.)	Column Study Number							Average Removal
	#1	#2	#3	#4	#5	#6	#7	
				PORT 1				
5	--	--	--	10.164	18.754	- 84.155	0.586	- 13.622
10	--	--	- 29.787	7.541	9.951	39.261	0.439	5.481
15	--	--	- 55.319	4.372	24.495	23.239	3.660	0.089
30	--	--	- 73.404	- 0.874	12.352	19.014	0.878	- 8.406
60	--	--	- 43.617	- 7.760	13.848	24.296	- 9.078	- 1.358
120	--	--	- 47.872	18.470	38.518	23.768	- 10.688	4.439
				PORT 3				
5	--	--	37.692	16.860	5.970	-253.830	- 9.200	- 40.502
10	--	--	- 22.308	10.432	38.242	23.550	-122.130	- 14.443
15	1.186	--	- 14.615	12.434	19.501	9.720	9.730	6.326
30	--	--	--	- 9.589	1.592	14.390	15.470	5.465
60	--	--	- 15.385	12.961	7.742	6.920	13.200	5.086
120	--	--	- 10.000	15.490	24.964	17.010	- 12.530	6.986
				PORT 5				
5	--	--	-812.370	1.803	-38.717	14.545	- 6.470	-168.242
10	--	--	-626.800	3.846	10.626	19.818	7.032	-117.096
15	--	--	--	-33.413	24.691	15.636	3.094	2.502
30	--	--	--	- 3.005	18.624	8.545	- 2.954	5.302
60	--	--	-698.970	- 0.481	8.810	16.364	- 24.754	-139.806
120	--	--	-631.960	3.245	11.283	26.909	- 23.769	-122.858

Note: 3 decimal place accuracy based on mathematical computation only

displayed much more efficient removal with averages of 29.73 and 18.75 percent after 2 hours of sedimentation. Iron removal is summarized in Table IV-16.

A majority of the column studies showed positive removal trends for lead. From Table IV-17, it is evident that each port, especially port 5, provided treatment. However, the magnitude of the negative results of column study 3 at port 5 have biased the average removals listed in Table IV-17 for the various sampling times. If these values are rejected, the average removal efficiencies are -2.62, 5.63, -3.45, 12.46, 16.82, and 23.23 percent, respectively, for the sampling times of 5, 10, 15, 30, 60 and 120 minutes. The average removals shown by ports 1 and 3, coupled with the recalculated values for port 5, suggest that 2 hours of settling will ultimately reduce the concentration of lead in Lake Eola stormwater by 20 percent.

Chromium removal by port or column study was not consistent as evidenced by the values listed in Table IV-18. Port 5 exhibited rather weak results. Column study 6 demonstrated the most consistent treatment with an average removal of approximately 27 percent for each port after 2 hours of sedimentation. The average two hour removals for ports 1, 3, and 5 were 7.85, 7.00 and 6.56 percent, respectively. These values indicate that plain sedimentation is essentially an ineffective treatment measure for chromium.

Calcium removals for each column study are listed in Table IV-19. Removal efficiencies were varied for each port as well as

TABLE IV-16

SUMMARY OF PERCENT IRON REMOVAL AND
AVERAGE REMOVAL FOR ALL SETTLING COLUMN STUDIES

Settling Time (Min.)	Column Study Number							Average Removal
	#1	#2	#3	#4	#5	#6	#7	
PORT 1								
5	32.967	0.000	--	11.680	33.495	- 23.640	6.604	10.184
10	2.015	- 7.500	- 1.639	9.900	-21.359	- 10.694	1.415	- 3.980
15	25.641	- 56.513	6.011	2.781	25.728	- 2.345	15.920	2.460
30	23.626	21.382	- 25.137	15.071	31.456	- 34.053	8.726	5.859
60	44.139	37.237	34.973	22.803	35.825	- 8.349	15.684	26.044
120	37.729	48.618	6.557	37.041	54.320	2.908	20.991	29.737
PORT 3								
5	20.274	- 0.710	44.048	12.896	-29.167	-114.740	- 7.516	-10.701
10	36.438	-103.800	10.317	-13.365	26.389	12.770	14.924	- 2.333
15	35.205	18.750	26.587	- 2.931	15.278	22.140	14.924	18.565
30	37.808	16.030	17.460	- 3.986	- 1.528	- 30.840	20.044	7.848
60	-29.178	30.980	34.524	9.730	21.667	- 55.000	17.429	- 1.884
120	26.027	34.510	39.286	17.937	- 4.306	16.080	1.743	18.753
PORT 5								
5	1.387	- 60.290	-523.220	0.795	-48.062	10.599	19.865	-85.561
10	39.112	- 57.609	-421.330	- 8.609	-10.078	6.169	- 0.677	-64.717
15	5.409	- 38.043	-490.050	-37.748	20.155	- 3.475	4.740	-77.001
30	41.748	- 11.594	-407.110	-23.311	3.721	15.117	0.339	-54.441
60	41.748	13.043	-347.870	-12.848	8.372	32.320	15.801	-35.633
120	48.266	10.870	-352.610	-11.788	9.922	53.345	6.208	-33.683

Note: 3 decimal place accuracy based on mathematical computation only

TABLE IV-17

SUMMARY OF PERCENT LEAD REMOVAL AND
AVERAGE REMOVAL FOR ALL SETTLING COLUMN STUDIES

Settling Time (Min.)	Column Study Number							Average Removal
	#1	#2	#3	#4	#5	#6	#7	
				PORT 1				
5	20.982	-16.799	--	4.643	3.089	21.083	11.111	4.119
10	33.929	-20.458	- 185.390	2.500	4.715	36.467	15.873	- 22.707
15	23.438	-70.840	- 27.400	0.000	4.715	29.345	25.132	- 3.950
30	28.348	- 1.527	- 98.630	7.500	5.366	27.635	25.132	- 4.299
60	31.696	16.489	- 1.830	15.357	13.984	40.741	23.545	19.357
120	18.973	28.092	- 157.990	30.714	17.886	41.880	26.984	- 1.053
				PORT 3				
5	- 6.250	- 7.126	76.857	13.699	1.741	-10.625	- 3.989	13.077
10	25.000	- 3.448	- 20.000	- 2.740	9.810	17.188	14.362	7.014
15	-47.656	9.655	52.143	6.507	8.070	15.000	12.234	18.149
30	28.646	6.322	47.286	3.425	4.589	17.188	21.809	18.423
60	23.958	26.437	58.857	10.274	3.797	24.375	18.351	24.826
120	29.948	22.989	59.571	16.096	13.449	39.375	- 1.330	24.160
				PORT 5				
5	- 6.250	-41.259	-1306.900	1.149	-35.032	36.164	29.529	-188.942
10	25.000	-42.657	-2106.900	- 4.215	5.096	33.699	16.873	-296.157
15	-47.656	-13.287	-1455.200	-20.307	7.643	40.274	12.655	-210.835
30	28.646	- 7.692	-1403.400	- 3.065	4.936	32.329	19.603	-189.813
60	23.958	4.895	-1455.200	1.533	9.236	39.726	21.588	-193.462
120	29.948	5.594	-1658.600	9.579	10.510	59.452	24.318	-217.031

Note: 3 decimal place accuracy based on mathematical computations only

TABLE IV-18

SUMMARY OF PERCENT CHROMIUM REMOVAL AND
AVERAGE REMOVAL FOR ALL SETTLING COLUMN STUDIES

Settling Time (Min.)	Column Study Number							Average Removal
	#1	#2	#3	#4	#5	#6	#7	
				PORT 1				
5	23.396	-4.918	--	12.450	1.361	-115.820	13.158	-11.729
10	-13.396	--	--	9.639	- 7.483	34.810	18.092	8.332
15	8.113	--	--	8.434	-11.095	22.150	22.039	9.766
30	- 6.792	--	--	2.811	7.143	21.520	19.408	8.817
60	10.189	-3.607	--	5.622	- 3.401	29.110	15.789	8.951
120	25.094	--	--	22.088	-45.238	29.110	8.224	7.856
				PORT 3				
5	- 7.724	--	--	19.850	1.954	-242.180	- 2.034	-46.026
10	- 1.220	--	- 2.781	8.240	7.166	23.130	-20.339	2.350
15	6.098	--	4.785	15.356	5.863	15.650	16.949	10.782
30	-18.089	--	-15.789	- 8.614	- 5.537	18.370	25.085	- 0.762
60	-18.089	--	9.091	15.356	-20.521	16.330	20.678	3.807
120	-19.106	--	14.354	19.850	- 9.772	27.210	9.492	7.004
				PORT 5				
5	0.943	--	--	- 2.273	-31.562	9.091	1.132	- 4.533
10	3.774	--	--	1.818	6.875	16.084	9.057	7.521
15	-13.396	--	--	-36.364	11.250	14.685	4.151	- 3.934
30	8.302	--	--	- 1.818	9.375	4.895	3.396	4.830
60	7.925	--	--	- 0.909	14.063	18.182	-19.623	3.927
120	8.868	--	--	4.091	- 3.437	25.175	- 1.887	6.562

Note: 3 decimal place accuracy based on mathematical computation only

TABLE IV-19

SUMMARY OF PERCENT CALCIUM REMOVAL AND
AVERAGE REMOVAL FOR ALL SETTLING COLUMN STUDIES

Settling Time (Min.)	Column Study Number							Average Removal
	#1	#2	#3	#4	#5	#6	#7	
PORT 1								
5	26.250	- 4.920	--	24.324	68.000	- 108.330	- 4.167	0.192
10	20.000	36.070	- 62.029	21.622	-28.800	50.000	-16.667	2.878
15	21.250	-122.950	- 13.793	8.108	43.200	45.830	0.000	- 2.621
30	16.250	34.430	- 6.897	5.405	57.600	33.330	- 8.333	18.826
60	36.250	- 9.840	- 17.241	32.432	63.200	25.000	-12.500	16.757
120	33.750	60.660	- 48.276	35.135	65.600	41.670	-29.167	22.766
PORT 3								
5	34.200	43.284	52.174	23.529	- 2.273	-1005.900	- 5.263	-122.883
10	27.400	- 1.493	- 8.696	- 2.941	29.545	23.500	36.842	14.883
15	19.200	46.269	2.174	0.000	- 4.545	17.600	31.579	16.043
30	34.200	41.791	4.348	0.000	-11.364	23.500	36.842	18.484
60	-1064.400	52.239	10.870	2.941	-95.455	- 11.800	34.211	-153.048
120	15.100	49.254	- 4.348	8.824	-59.091	17.600	21.053	6.915
PORT 5								
5	31.633	6.897	- 1.160	- 6.452	-43.750	31.818	21.875	5.837
10	38.776	6.897	- 1.160	-16.129	-28.125	18.182	18.750	5.313
15	32.653	37.931	- 1.020	-35.484	-37.500	0.000	- 6.250	- 1.381
30	41.837	32.754	- 1.120	-32.258	-56.250	13.636	12.500	- 1.586
60	40.816	36.207	-460.000	-12.903	-34.375	18.182	9.375	- 57.528
120	45.918	29.310	-960.000	-19.355	-87.500	31.818	12.500	-135.329

Note: 3 decimal place accuracy based on mathematical computation only

for each column study. Comparatively, column studies 1, 2, and 6, all ports considered, exhibited the most efficient removal. The average two hour removal values for ports 1, 3 and 5 were 22.76, 6.915 and -135.32 percent, respectively. The results above indicate that plain sedimentation is not adequate to effect efficient calcium removal from Lake Eola stormwater.

CHAPTER V

DATA ANALYSIS

A statistical analysis was performed on the column study data that were presented in Chapter IV. A relationship was sought between the percent removal of the various stormwater constituents and known time and settling variables. The linear regression equations that were developed for the statistical data analysis are presented below.

$$\% \text{ Removal } (X) = mt + b \tag{1}$$

$$\% \text{ Removal } (X) = m \ln t + b \tag{2}$$

$$\% \text{ Removal } (X) = m \text{ s.v.} + b \tag{3}$$

$$\% \text{ Removal } (X) = m \ln \text{s.v.} + b \tag{4}$$

$$(\% \text{ Removal } (X))^{-1} = m(\text{s.v.}) + b \tag{5}$$

where:

X = any stormwater constituent

t = time

sv = settling velocity

m = slope

b = intercept

The calculations that were required to determine values for the slope and intercept of the regression equations were performed using the Statistical Analysis System computer program (SAS, 1979).

These equations were intended to provide the engineer or designer with a means of predicting the removal efficiency of a stormwater detention or sedimentation facility.

The results of the statistical analysis are presented in Tables V-1 through V-3 and in Tables V-4 through V-6 for the general water quality and metals parameters, respectively. The results are arranged in terms of the slope (m), intercept (b), correlation coefficient (r), level of significance (a), and the number of observations (n). A correlation coefficient (r) of 1 indicates perfect correlation or a perfectly linear relationship. The level of significance (a) indicates the probability of rejecting the null hypothesis, when in fact, it is true. A relationship that exhibited a level of significance of 0.05 or less was accepted as valid. The reader should note that arsenic removal has been omitted from the statistical analysis due to the latent problems that were discovered with the apparatus that was used in the metals analysis.

Statistical Results for the General Water Quality Parameters

The time correlation results for equation 1 in Table V-1 show that none of the general water quality parameters produced correlation coefficients that exceeded 0.51. Thus, a perfectly linear relationship was lacking for the time regressions; however, many of the constituents produced acceptable levels of significance.

Ports 1 and 5 both exhibited acceptable levels of significance for the removal of TSS, VSS, COD, TOC and TP that were greater than 0.05. Port 5 also had an acceptable level of significance for

TABLE V-1

SUMMARY OF THE STATISTICAL DATA PRODUCED BY REGRESSION ANALYSIS OF EQUATION 1[1] FOR THE GENERAL WATER QUALITY PARAMETERS

		Percent Removal							
		TSS	VSS	NVSS	COD	TKN	NH_3	TOC	TP
Port 1	m	0.61	0.93	0.21	0.20	- 0.33	0.09	0.17	0.18
	b	- 3.27	-25.42	16.21	22.16	25.37	26.76	4.50	22.30
	r	.285	.284	.151	.359	- .230	.251	.414	.505
	a	.050	.050	.305	.020	.116	.109	.028	.000
	n	48	48	48	42	48	42	28	49
Port 3	m	0.11	0.14	- 0.03	- 0.07	0.08	0.11	0.17	0.42
	b	34.74	38.35	23.61	14.05	9.15	6.17	17.02	-22.17
	r	.258	.296	- .002	- .024	.147	.216	.416	.166
	a	.074	.039	.987	.882	.314	.169	.014	.260
	n	49	49	49	42	49	42	34	48
Port 5	m	0.28	0.16	0.39	0.28	0.09	0.26	0.30	0.32
	b	29.92	33.13	24.84	3.07	3.41	-11.22	-16.31	3.21
	r	.402	.300	.459	.352	.142	.223	.383	.475
	a	.004	.038	.001	.024	.336	.156	.023	.001
	n	49	48	48	41	48	42	35	49

1 Equation 1: Percent Removal (X) = mt + b

the removal of NVSS; whereas, port 3 only produced acceptable values for VSS and TOC. Thus, it is apparent that a direct relationship does exist between the removal of the parameters mentioned above and time.

The poor results that were displayed by port 3 for regression equation 1 are difficult to justify. The average removals shown in Table IV-2 for TSS definitely indicate a trend of increased removal with time. The level of significance listed in Table V-1 for TSS removal at port 3 is 0.074, which is close to the accepted value of 0.05. However, it appears that a large majority of the constituents did not accompany the suspended solids during settling. The rate of particle agglomeration may have been altered between ports 1 and 3 by hindered settling forces that impeded the settling motion of the suspended constituents.

The results of the regression analysis for equation 2 are presented in Table V-2 for the general water quality parameters. The highest correlation coefficient for this relationship occurred for total phosphorus removal at port 1 and had a value of 0.639. Moreover, this correlation coefficient was also accompanied by an acceptable level of significance which indicates that a direct relationship exists between phosphorus removal and the natural log of time. Based on levels of significance, similar relationships appear possible at port 1 for COD, NH_3 and TOC removal. Although TSS and VSS removals at port 1 produced meaningful levels of significance when correlated to time, they did not produce acceptable values when correlated to the natural log of time.

TABLE V-2

SUMMARY OF THE STATISTICAL DATA PRODUCED BY REGRESSION ANALYSIS OF EQUATION 2[1] FOR THE GENERAL WATER QUALITY PARAMETERS

		Percent Removal							
		TSS	VSS	NVSS	COD	TKN	NH_3	TOC	TP
Port 1	m	14.74	19.29	9.99	9.24	- 1.92	6.27	4.95	8.46
	b	-22.08	-42.64	- 5.34	0.79	15.55	9.23	- 3.81	2.48
	r	.269	.249	.217	.466	.066	.332	.426	.639
	a	.064	.068	.138	.002	.645	.032	.024	.000
	n	47	47	47	41	47	41	27	48
Port 3	m	9.43	11.09	1.93	2.03	4.76	4.45	7.51	6.64
	b	8.10	7.65	12.36	4.21	- 2.13	- 2.80	0.09	-22.05
	r	.416	.478	.041	.072	.232	.269	.523	.115
	a	.003	.001	.781	.651	.109	.084	.002	.436
	n	48	48	48	41	48	41	33	47
Port 5	m	12.41	10.38	13.85	7.92	2.75	4.39	3.70	8.35
	b	1.58	5.84	- 2.68	- 9.05	- 1.29	-12.59	-13.79	- 8.70
	r	.506	.449	.509	.361	.140	.163	.215	.445
	a	.000	.001	.000	.020	.341	.301	.214	.001
	n	48	47	47	40	47	41	34	48

[1] Equation 2: Percent Removal (X) = $m \ln(t) + b$

The statistical results at port 3 for regression equation 2 improved slightly over those associated with equation 1. A level of significance of 0.003 suggests that a direct relationship exists between TSS removal and the natural log of time. The remaining parameters of significance were VSS and TOC. These parameters exhibited similar statistical results for the time regressions of equation 1.

As shown in Table V-2, the correlation coefficients produced by equation 2 at port 5 exceeded those produced by equation 1 for TSS, VSS, NVSS, COD and TP removal. The levels of significance pertaining to the natural log of time regressions were also more reassuring.

The results of the linear regressions for equations 3, 4 and 5 are summarized in Table V-3 for the general water quality parameters. The parameters that produced acceptable levels of significance for equation 3 also generated accepted values for equation 4. These parameters include: COD, NH_3, TOC and TP removal. Ammonia nitrogen removal was not described by either equations 1 or 2; however, equations 3 and 4 express valid relationships between percent removal and settling velocity. The results of the regression analysis for equation 5 were not favorable for any of the general water quality parameters. However, positive correlations for this relationship indicates that the inverse of percent removal becomes smaller in magnitude as settling velocity decreases. An alternative statement is that percent removal increases as settling progresses.

TABLE V-3

SUMMARY OF THE STATISTICAL DATA PRODUCED BY REGRESSION ANALYSIS OF EQUATIONS 3, 4, and 5[1] FOR THE GENERAL WATER QUALITY PARAMETERS

		Percent Removal							
		TSS	VSS	NVSS	COD	TKN	NH_3	TOC	TP
Equation 3	m	-25.42	-20.55	-18.85	-40.79	-16.94	-47.17	-35.32	-55.39
	b	38.85	35.55	32.44	27.14	14.18	23.35	17.68	25.28
	r	- .102	- .062	- .067	- .250	- .105	- .308	- .325	- .223
	a	.256	.494	.458	.009	.246	.001	.003	.012
	n	125	124	124	107	124	108	83	125
Equation 4	m	- 7.64	- 8.97	- 4.51	- 8.60	- 0.62	- 9.91	- 8.17	-12.93
	b	16.88	11.73	18.64	- 0.30	9.29	- 8.25	- 7.54	-14.71
	r	- .156	- .137	- .082	- .271	-.020	- .332	- .374	- .268
	a	.082	.128	.366	.005	.828	.000	.001	.002
	n	125	124	124	107	124	108	83	125
Equation 5	m	.079	- 2.52	- 1.30	11.99	14.43	9.88	- 5.17	- 0.04
	b	.781	1.36	3.52	0.43	10.69	17.40	3.58	0.04
	r	.002	.066	.017	.170	.098	.058	.081	.109
	a	.982	.466	.849	.080	.279	.549	.469	.226
	n	124	123	123	106	123	107	82	124

[1] Equation 3: Percent Removal (X) = m(S.V.) + b
Equation 4: Percent Removal (X) = m ln(S.V.) + b
Equation 5: $(\text{Percent Removal}(X))^{-1}$ = m(S.V.) + b

Statistical Results for the Metals Parameters

From Table V-4, it is apparent that metals removals were not correlated successfully to time. Acceptable levels of significance were produced only by Fe, Pb and Ca removal at ports 1, 3 and 5, respectively. The poor time correlations were probably due to the particle sizes associated with the stormwater metals content. Plain sedimentation would be incapable of achieving significant metals removals if the metal constituents were of a colloidal size.

The results of the regressions performed for equation 2 are presented in Table V-5 for the metals parameters. Inspection of this table reveals that the results showed no improvement over those exhibited for equation 1. Iron and lead were the only parameters that produced meaningful results. The fact that iron removal and especially lead removal were described by equations 1 and 2 is significant. Lead is a heavy metal that is typically associated with urban stormwater runoff and the data analysis has indicated that lead removal is possible by sedimentation or detention.

The statistical results improved tremendously for metals removals when regressions were performed for settling velocity and the natural log of settling velocity. Although far from perfect correlation, the values shown in Table V-6 for the correlation coefficient improved for each parameter. The statistical analysis for equation 3 produced meaningful levels of significance for Zn,

TABLE V-4

SUMMARY OF THE STATISTICAL DATA PRODUCED BY REGRESSION ANALYSIS OF EQUATION 1[1] FOR THE METALS PARAMETERS

		Percent Removal								
		Zn	Cd	Ni	Cu	Mg	Fe	Pb	Cr	Ca
Port 1	m	- 0.29	- 0.18	0.46	0.15	0.07	0.27	0.11	0.08	0.20
	b	11.68	30.18	-43.67	4.76	- 4.65	0.82	- 5.91	1.87	1.88
	r	- .123	- .032	.083	.148	.074	.492	.081	.132	.211
	a	.414	.828	.586	.316	.678	.000	.584	.429	.150
	n	46	48	45	48	34	48	48	38	48
Port 3	m	0.53	- 0.25	0.33	0.07	0.23	0.14	0.12	0.18	0.08
	b	-47.15	48.55	-66.92	- 5.92	-14.31	- 0.61	12.95	- 9.82	-39.75
	r	.100	- .069	.036	.062	.147	.179	.324	.141	- .009
	a	.527	.638	.839	.672	.392	.218	.023	.373	.954
	n	43	49	35	49	36	49	49	42	49
Port 5	m	0.54	0.17	0.42	- 0.04	- 0.28	0.41	0.15	0.06	- 1.28
	b	-109.07	-44.35	-94.85	-45.11	-85.28	-75.08	-221.99	- 0.04	20.83
	r	.049	.010	.027	- .082	- .098	.050	- .041	.199	- .316
	a	.737	.948	.858	.574	.587	.733	.779	.252	.027
	n	49	49	47	49	33	49	49	35	49

1 Equation 1: Percent Removal (X) = mt + b

TABLE V-5

SUMMARY OF THE STATISTICAL DATA PRODUCED BY REGRESSION ANALYSIS OF EQUATION 2[1] FOR THE METALS PARAMETERS

		Percent Removal								
		Zn	Cd	Ni	Cu	Mg	Fe	Pb	Cr	Ca
Port 1	m	- 0.89	2.69	4.52	3.56	0.76	6.09	1.78	2.95	5.33
	b	2.59	12.27	-34.27	- 0.53	- 3.65	- 6.56	- 6.17	- 3.65	- 5.95
	r	.017	.040	.050	.122	.040	.415	.062	.182	.205
	a	.911	.787	.743	.408	.823	.003	.678	.275	.163
	n	45	47	44	47	33	47	47	37	47
Port 3	m	8.28	4.48	0.73	1.51	4.29	3.55	5.25	3.64	- 3.74
	b	-44.47	21.09	-47.85	- 6.89	-15.48	- 5.26	0.91	-11.85	-21.28
	r	.080	.122	.008	.074	.133	.171	.406	.140	.027
	a	.613	.405	.965	.615	.438	.241	.004	.375	.856
	n	41	48	34	48	35	48	48	41	48
Port 5	m	- 2.56	0.30	-11.80	- 9.75	-14.99	- 2.57	-34.56	.159	-23.98
	b	-67.99	-33.12	-35.36	-13.80	-41.93	-43.22	-91.85	- 2.23	38.82
	r	.023	.004	.116	.164	.100	.027	.098	.195	.243
	a	.875	.979	.439	.260	.580	.856	.503	.262	.106
	n	48	48	46	48	32	48	48	34	48

[1] Equation 2: Percent Removal (X) = m ln(t) + b

TABLE V-6

SUMMARY OF THE STATISTICAL DATA PRODUCED BY REGRESSION ANALYSIS OF EQUATIONS 3, 4, and 5[1] FOR THE METALS PARAMETERS

		Percent Removal								
		Zn	Cd	Ni	Cu	Mg	Fe	Pb	Cr	Ca
Equation 3	m	-175.67	- 77.65	- 87.26	- 44.08	-129.65	- 90.35	-155.27	- 32.00	- 4.20
	b	- 2.34	24.11	- 34.86	- 4.09	- 6.30	4.80	- 34.69	7.96	- 18.29
	r	- .274	- .170	- .136	- .152	- .204	- .218	- .106	- .232	- .006
	a	.003	.058	.162	.091	.058	.015	.239	.022	.947
	n	117	125	108	125	87	125	125	97	125
Equation 4	m	- 28.09	- 9.26	- 21.70	- 9.79	- 17.52	- 18.06	- 32.04	- 5.54	- 0.02
	b	-100.90	- 12.50	-100.71	- 34.83	- 72.21	- 53.82	-137.63	- 10.82	- 19.21
	r	- .221	- .104	- .167	- .173	- .141	- .223	- .112	- .210	- .000
	a	.016	.247	.084	.054	.191	.012	.212	.039	.999
	n	117	125	108	125	87	125	125	97	125
Equation 5	m	0.16	- 3.23	9.86	- 1.27	0.07	0.29	- 1.86	0.27	- 2.19
	b	- 0.08	3.89	2.56	1.90	0.06	0.78	1.24	- 0.02	3.63
	r	.051	.044	.112	.024	.037	.008	.049	.222	.029
	a	.588	.629	.248	.794	.735	.932	.588	.029	.748
	n	116	124	107	124	86	124	124	96	124

[1] Equation 3: Percent Removal (X) = m(S.V.) + b
Equation 4: Percent Removal (X) = m ln(S.V.) + b
Equation 5: (Percent Removal (X))$^{-1}$ = m(S.V.) + b

Cd, Mg, Fe and Cr. The analysis pertaining to equation 4 produced meaningful levels of significance for Zn, Cu, Fe and Cr. The levels of significance shown by both Cd and Mg for equation 3 and Cu for equation 4 exceeded 0.05. However, the difference between the values of level of significance that were determined for the elements above and 0.05 was not great. Thus, these relationships were perceived to warrant further consideration.

The results of the linear regression computations for equation 5 are listed in Table V-6. Inspection of this table reveals that Cr exhibited an acceptable level of significance for this relationship. However, the removal percentages predicted by this equation are very low (< 1.0%). It is apparent that metals removal by settling Lake Eola stormwater is not described by equation 5.

Many of the equations that are statistically valid for the removal of metals predict negative efficiencies. These equations simply reflect the variability and inconsistency of the metals removal data. Further discussions will focus on those equations that predict positive removal efficiencies.

Constituent Removal by Regression and Isoconcentration Lines

The regression equations that best describe the removal of each stormwater constituent at the column sampling port depths of 1.1, 3.0 and 4.5 feet are presented in Tables V-7 through V-9, respectively. These equations were selected according to

TABLE V-7

POLLUTANT MASS LOADING COMPARISON BETWEEN UNTREATED AND SETTLED LAKE EOLA STORMWATER AT A SETTLING DEPTH OF 1.1 FEET

Stormwater Runoff Constituents	Average Initial Concentration	Best Fit Regression Equation	Percent Removed[1]	Concentration After Treatment	Untreated Mass Loadings[2] (lbs/yr)	Settled Mass Loadings[2] (lbs/yr)
TSS	145.9 mg/l	0.61 (t) - 3.27	33.3	97.3 mg/l	170,440	113,676
VSS	89.9 mg/l	0.93 (t) - 25.42	30.4	62.6 mg/l	105,021	73,136
NVSS	56.0 mg/l			56.0 mg/l	65,419	65,425
COD	168.9 mg/l	0.20 (t) + 22.16	34.2	111.1 mg/l	197,309	129,840
TKN	4.2 mg/l			4.2 mg/l	4,906	4,907
NH_3	0.5 mg/l	6.27 ln(t) + 9.23	34.9	0.33 mg/l	584	380
TOC	139.9 mg/l	4.95 ln(t) - 3.81	16.5	116.8 mg/l	163,445	136,477
TP	1.0 mg/l	8.46 ln(t) + 2.48	37.1	0.63 mg/l	1,168	735
Zn	559 ppb	-28.09 ln(S.V.) - 100.90	11.4	495 ppb	653	579
Cd	34 ppb	-77.65 (S.V.) + 24.11	22.7	26 ppb	40	31
Ni	38 ppb			38 ppb	44	44
Cu	90 ppb	-9.79 ln(S.V.) - 34.83	4.3	86 ppb	105	101
Mg	1391 ppb			1391 ppb	1,625	1,625
Fe	1455 ppb	0.27 (t) + 0.82	17.0	1208 ppb	1,700	1,411
Pb	659 ppb			659 ppb	770	770
Cr	33 ppb	-32.00 (S.V.) + 7.96	7.4	31 ppb	39	36
Ca	46.5 mg/l			46.5 mg/l	54,321	54,321

[1] Percent removed was calculated for 60 minutes of settling.

[2] Based on 1.4 x 10^8 gallons/year of stormwater runoff.

TABLE V-8

POLLUTANT MASS LOADING COMPARISON BETWEEN UNTREATED AND SETTLED LAKE EOLA STORMWATER AT A SETTLING DEPTH OF 3.0 FEET

Stormwater Runoff Constituents	Average Initial Concentration	Best Fit Regression Equation	Percent Removed[1]	Concentration After Treatment	Untreated Mass Loadings[2] (lbs/yr)	Settled Mass Loadings[2] (lbs/yr)
TSS	145.9 mg/l	9.43 ln(t) + 8.10	46.7	77.8 mg/l	170,440	90,894
VSS	89.9 mg/l	11.09 ln(t) - 7.65	53.1	42.2 mg/l	105,021	49,302
NVSS	56.0 mg/l			56.0 mg/l	65,419	65,419
COD	168.9 mg/l	-8.60 ln(S.V.) - 0.30	25.5	125.8 mg/l	197,309	146,972
TKN	4.2 mg/l			4.2 mg/l	4,906	4,906
NH_3	0.5 mg/l	-9.91 ln(S.V.) - 8.25	21.4	.39 mg/l	584	456
TOC	139.9 mg/l	7.51 ln(t) + 0.09	30.8	96.8 mg/l	163,445	113,091
TP	1.0 mg/l	-12.93 ln(S.V.) - 14.71	24.0	.76 mg/l	1,168	888
Zn	559 ppb			559 ppb	653	653
Cd	34 ppb	-77.05 (S.V.) + 24.11	20.3	27.1 ppb	40	47
Ni	38 ppb			38 ppb	44	44
Cu	90 ppb			90 ppb	105	105
Mg	1391 ppb			1391 ppb	1,625	1,625
Fe	1455 ppb	-18.06 ln(S.V.) - 53.82	0.3	1450 ppb	1,700	1,694
Pb	659 ppb	5.25 ln(t) + 0.91	22.4	511 ppb	770	597
Cr	33 ppb	-32.00 (S.V.) + 7.96	6.4	31 ppb	39	36
Ca	46.5 mg/l			46.5 mg/l	54,321	54,321

1 Percent removed was calculated for 60 minutes of settling.

2 Based on 1.4 x 10^8 gallons/year of stormwater runoff.

TABLE V-9

POLLUTANT MASS LOADING COMPARISON BETWEEN UNTREATED AND SETTLED LAKE EOLA STORMWATER AT A SETTLING DEPTH OF 4.5 FEET

Stormwater Runoff Constituents	Average Initial Concentration	Best Fit Regression Equation	Percent Removed[1]	Concentration After Treatment	Untreated Mass Loadings[2] (lbs/yr)	Settled Mass Loadings[2] (lbs/yr)
TSS	145.9 mg/l	12.41 ln(t) + 1.58	52.4	69.4 mg/l	170,440	170,440
VSS	89.9 mg/l	10.38 ln(t) + 5.84	48.3	46.5 mg/l	105.021	54,321
NVSS	56.0 mg/l	13.85 ln(t) - 2.68	54.0	25.8 mg/l	65,419	30,140
COD	168.9 mg/l	7.92 ln(t) - 9.05	23.4	129.4 mg/l	197,309	151,165
TKN	4.2 mg/l			4.2 mg/l	4,906	4,906
NH_3	0.5 mg/l	-9.91 ln(S.V.) - 8.25	21.4	0.39 mg/l	584	456
TOC	139.9 mg/l	-8.17 ln(S.V.) - 7.54	13.6	120.9 mg/l	163,445	141,218
TP	1.0 mg/l	0.32 (t) + 3.21	22.4	0.78 mg/l	1,168	911
Zn	559 ppb			559 ppb	653	653
Cd	34 ppb	-77.65 (S.V.) + 24.11	17.6	28 ppb	40	33
Ni	38 ppb			38 ppb	44	44
Cu	90 ppb			90 ppb	105	105
Mg	1391 ppb			1391 ppb	1,625	1,625
Fe	1455 ppb			1455 ppb	1,700	1,700
Pb	659 ppb			659 ppb	770	770
Cr	33 ppb	-32.00 (S.V.) + 7.96	5.4	31.2 ppb	39	36
Ca	46.5 mg/l			46.5 mg/l	54,321	54,321

1 Percent removed was calculated for 60 minutes.

2 Based on 1.4×10^8 gallons/year of stormwater runoff.

correlation coefficient and level of significance. Equations that predicted negative removals for the comparison conditions of depth and settling time were omitted. In addition, Tables V-7, V-8 and V-9 present a comparison between mass loadings of stormwater constituents to Lake Eola with and without treatment by sedimentation or detention.

Table V-10 presents a comparison between the percent removals predicted by the regression equations and the average of the percent removals observed during the column studies for each port. This table indicates that for most cases the observed average percent removals were greater than those that are predicted by linear regression.

Isoconcentration lines were developed for total suspended solids and total phosphorus removals and are shown in Figures V-1 and V-2, respectively. The percent removal predicted by linear regression and by the isoconcentration lines are compared in Table V-11. The comparison was based on settling depths of 3.0 and 4.5 feet and a settling time of 60 minutes. Table V-11 shows that the percent removals associated with the isoconcentration lines and the regression equations are similar in magnitude.

Trophic Status of Lake Eola

The effect that sedimentation may have on the productivity of Lake Eola can be assessed by utilizing lake trophic state models. As noted in Chapter II, Lake Eola has been classified

TABLE V-10

COMPARISON OF OBSERVED AVERAGE POLLUTANT REMOVALS AND PERCENT REMOVALS PREDICTED BY LINEAR REGRESSION [1]

Stormwater Runoff Constituent	Port 1		Port 3		Port 5	
	Observed Average Percent Removal	Predicted Percent Removal	Observed Average Percent Removal	Predicted Percent Removal	Observed Average Percent Removal	Predicted Percent Removal
TSS	52.8	33.3	50.8	46.7	50.9	52.4
VSS	64.0	30.4	50.1	53.1	48.4	48.3
NVSS					37.6	54.0
COD	36.0	34.2	20.6	25.5	27.6	23.4
TKN						
NH_3	37.4	34.9	34.4	21.4	13.0	21.4
TOC	23.5	16.5	34.7	30.8	1.9	13.6
TP	29.5	37.1	1.3	24.0	24.4	22.4
Zn	- 5.0	11.4				
Cd	58.9	22.7	37.2	20.3	-12.5	17.6
Ni						
Cu	29.6	4.3				
Mg						
Fe	26.0	17.0	- 1.9	0.3		
Pb			24.8	22.4		
Cr	9.0	7.4	3.8	6.4	3.9	5.4
Ca						

1 Comparison based on 60 minutes of settling.

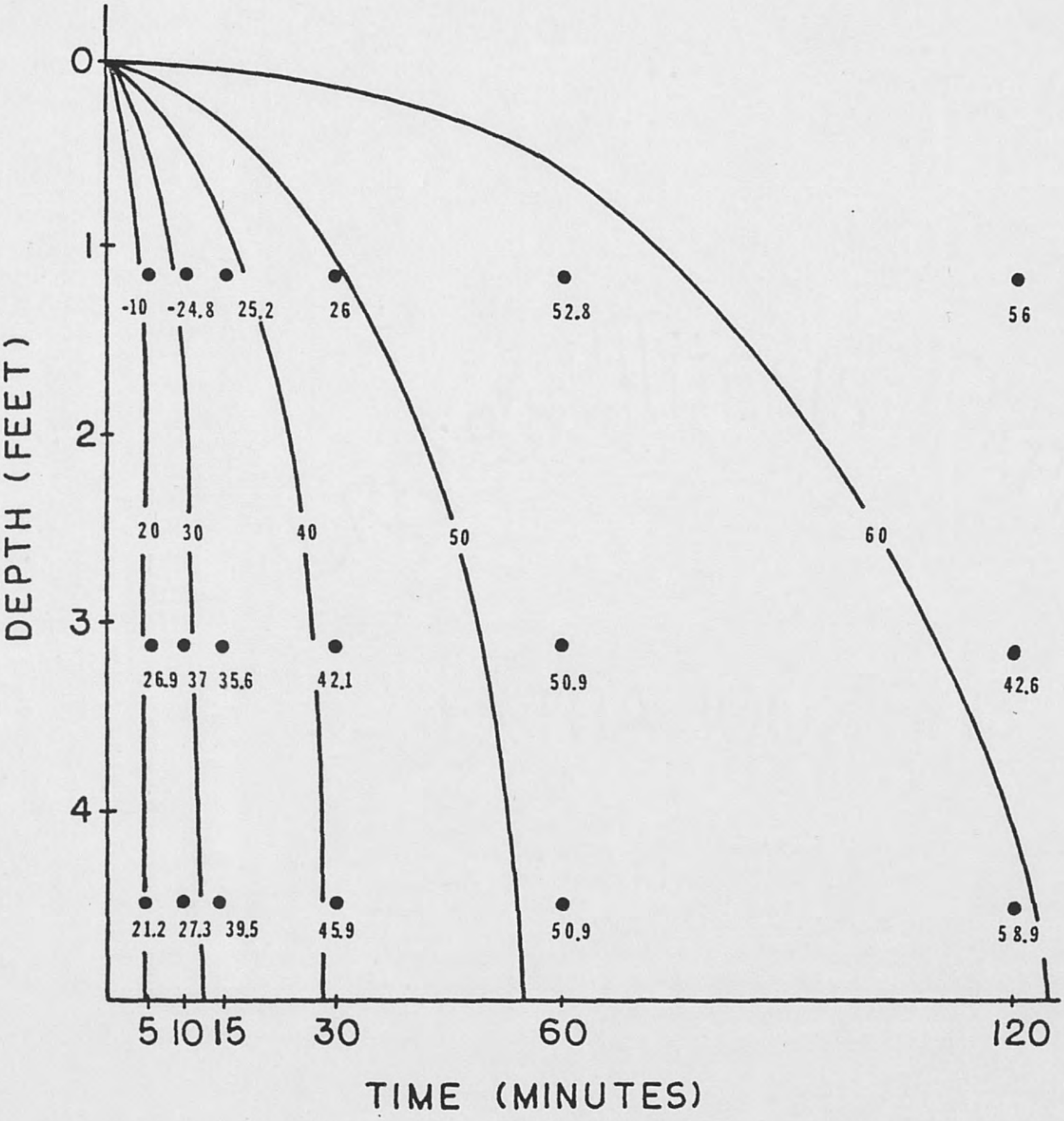


Fig. V-1. Isoconcentration lines for suspended solids removal for settled stormwater runoff from the Lake Eola watershed.

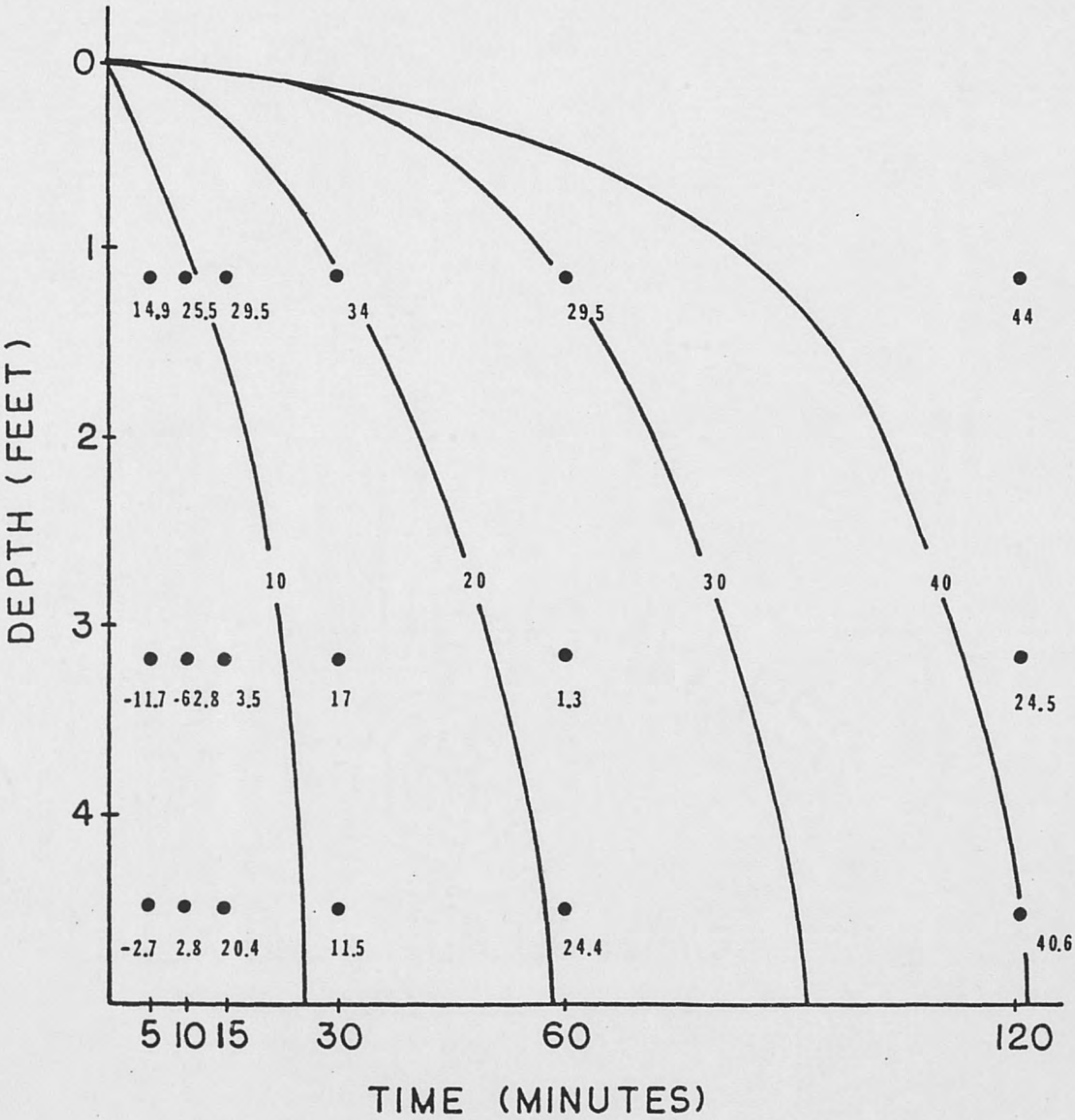


Fig. V-2. Isoconcentration lines for total phosphorus removal for settled stormwater runoff from the Lake Eola watershed.

TABLE V-11

COMPARISON OF PERCENT REMOVALS FOR TOTAL SUSPENDED SOLIDS AND TOTAL PHOSPHORUS BY LINEAR REGRESSION AND ISOCONCENTRATION LINES

Settling Depth	Total Phosphorus[1]		Total Suspended Solids[1]	
	Percent Removal by Linear Regression	Percent Removal by Isoconcentration Lines	Percent Removal by Linear Regression	Percent Removal by Isoconcentration Lines
3.0 feet	24.0	29.9	46.7	55.7
4.5 feet	22.4	27.8	52.4	54.0

[1] Settling time for comparison purposes was 60 minutes.

as eutrophic according to the models of Vollenweider, Dillon and Larsen-Mercier.

Vollenweider expressed the trophic status of a lake as a function of the areal phosphorus loading rate, the mean depth of the lake and the flushing rate (Wanielista, 1978). The Vollenweider model is shown in Figure V-3. The vertical axis represents the annual phosphorus loading to a lake in grams per square meter of lake surface area. The horizontal axis represents the ratio of the mean lake depth ($\overline{z}$) in meters and the hydraulic residence time (Tw) in years. Lake Eola has a mean depth of 3.5 meters and a hydraulic residence time of 0.64 years (Marshall, 1980). Marshall (1980) reported a phosphorus loading to the lake of 1.28 $g/m^2/yr$. However, based on the average TP concentration listed in Table IV-1 of 1.0 mg/l, an annual runoff contribution of 1.4 x 10^8 gallons and a lake area of 27 acres, the phosphorus loading is computed to be 4.85 $g/m^2/yr$. For comparison purposes, both loadings are plotted in Figure V-3 along with corresponding loadings for treated stormwater runoff. It was assumed that the treated runoff was settled quiescently for 60 minutes in an ideal 4.5 foot sedimentation basin. From Table V-9, a removal efficiency of 22.4 percent is listed for these conditions. Furthermore, an average TP removal of 24.4 percent was experienced for similar conditions during the column studies (see Table IV-9). Based on this information, a TP reduction of 22.4 percent was assumed for the settled runoff. Therefore, the phosphorus loading that was

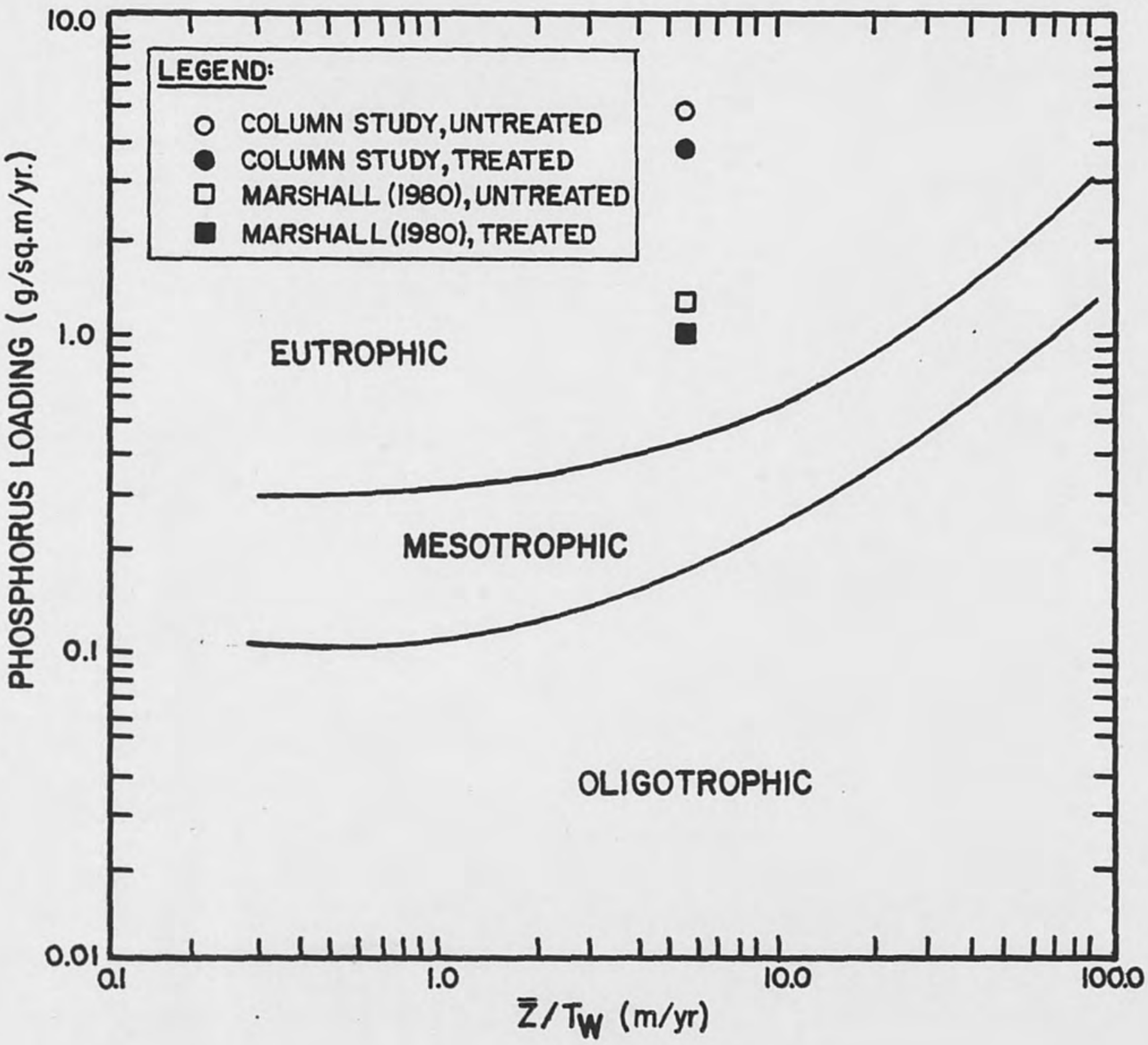


Fig. V-3. Trophic state comparison for Lake Eola using the Vollenweider model.

SOURCES: Vollenweider, R.A. "Möglichkeiten and Grenzen Elementarischen Modelle der Stoffbilanz von Seen," n. 10, cited by Martin P. Wanielista, Stormwater Management: Quantity and Quality, p. 344. Ann Arbor: Ann Arbor Science Publishers, Inc., 1978.

Marshall, Frank E. "Phosphorus Dynamics of Lake Eola Sediments." Master's Thesis, University of Central Florida, 1980.

reported by Marshall (1980) was reduced to 0.99 $g/m^2/yr$ and the column study loading was reduced to 3.76 $g/m^2/yr$. However, as seen in Figure V-3, eutrophic conditions are associated with Lake Eola for both untreated and treated runoff. Thus, it is apparent that plain sedimentation or detention will not improve the trophic state of Lake Eola according to the Vollenweider model.

The Dillon model is quite similar to Vollenweider's model, however, Dillon addressed the capacity of lake sediments to retain nutrients. Dillon introduced the nutrient retention coefficient, (R), that is defined as the ratio of the phosphorus mass entering a lake to the phosphorus mass leaving. The phosphorus loading parameter for the Dillon model is $L(1-R)/\rho$, and it appears as the vertical axis of the model in Figure V-4. The value of L is simply the Vollenweider phosphorus loading in $g/m^2/yr$ and ρ is the flushing per year which is merely the inverse of the hydraulic retention time. For Lake Eola R is given as 0.65 and ρ as 1.56/yr (Marshall, 1980). Marshall (1980) reported a Dillon phosphorus loading of 0.29 g/m^2; whereas the calculated value for the column study data is 1.09 g/m^2. Following the same treatment assumptions that were considered for the Vollenweider model, the foregoing loadings were reduced 22.4 percent to 0.23 g/m^2 and 0.85 g/m^2, respectively. As shown in Figure V-4, treatment by settling was ineffective at improving the trophic state of Lake Eola.

The Larsen-Mercier trophic state model is shown in Figure V-5. This particular model also considers nutrient retention by

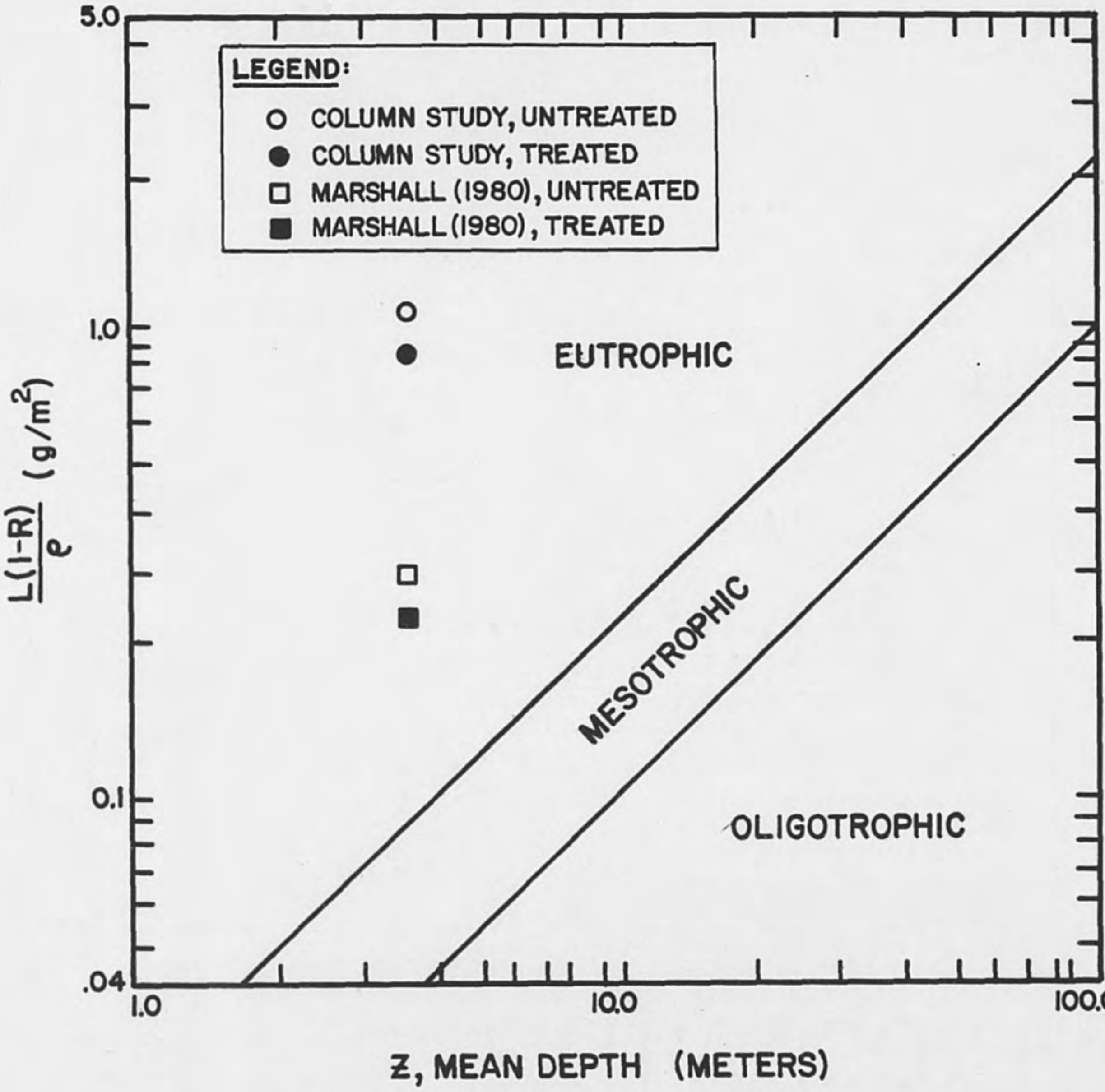


Fig. V-4. Trophic state comparison for Lake Eola using the Dillon Model.

SOURCES: Dillon, P.J. "The Phosphorus Budget of Cameron Lake, Ontario: The Importance of Flushing Rate to the Degree of Autrophy of Lakes," n. 11, cited by Martin P. Wanielista, Stormwater Management: Quantity and Quality, p. 346. Ann Arbor: Ann Arbor Science Publishers, Inc., 1978.

Marshall, Frank E. "Phosphorus Dynamics of Lake Eola Sediments." Master's Thesis, University of Central Florida, 1980.

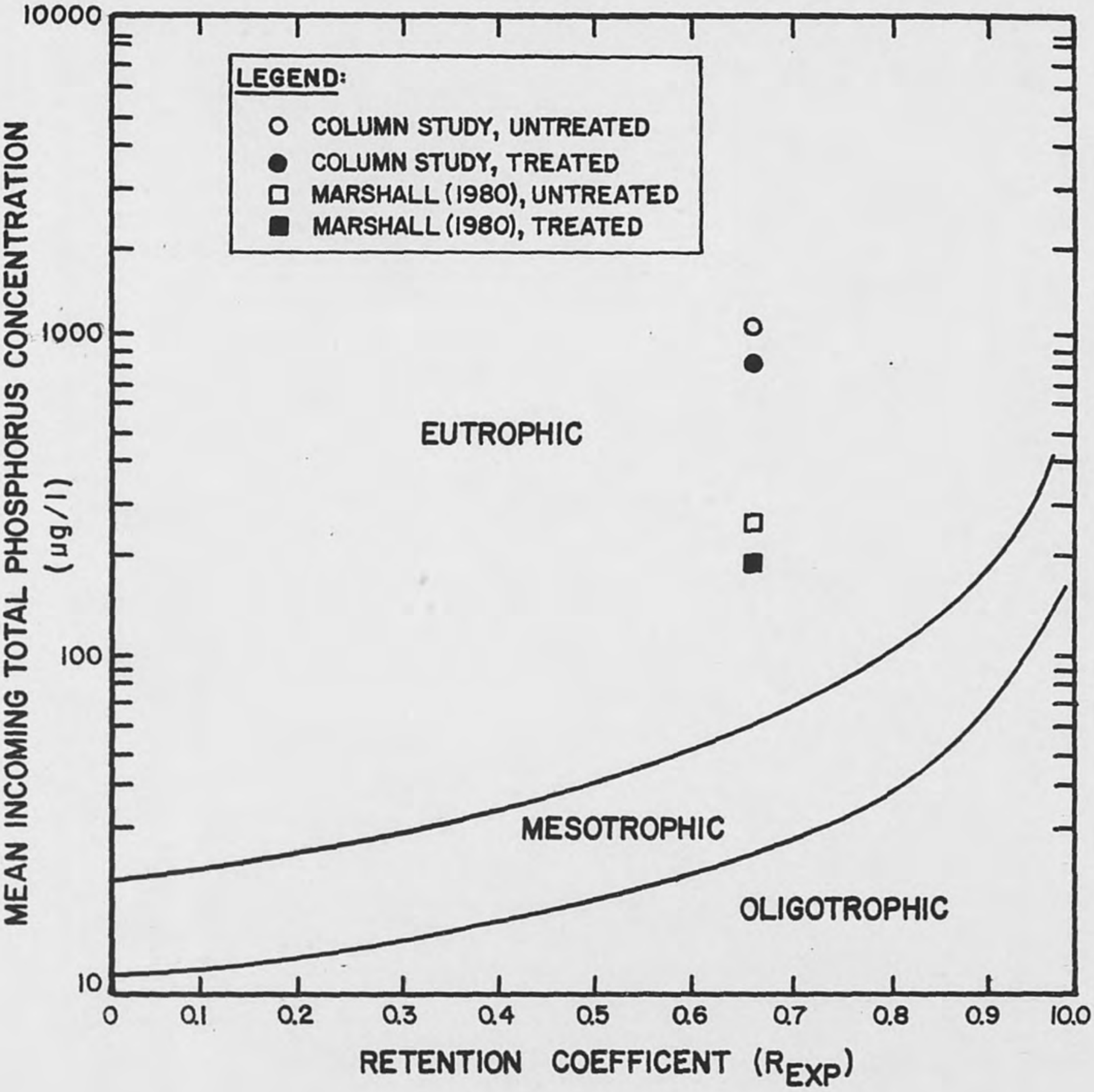


Fig. V-5. Trophic state comparison for Lake Eola using the Larsen-Mercier Model.

SOURCES: Larsen, D.P., et al. "Modeling Algal Growth Dynamics in Shagawa Lake, Minnesota," n. 13, cited by Martin P. Wanielista, Stormwater Management: Quantity and Quality, p. 346. Ann Arbor: Ann Arbor Science Publishers, Inc., 1978.

Marshall, Frank E. "Phosphorus Dynamics of Lake Eola Sediments." Master's Thesis, University of Central Florida, 1980.

the lake system. As shown in Figure V-5, trophic state is described by the mean incoming total phosphorus concentration in micrograms per liter (μg/l) and the retention coefficient, (R_{exp}). Values for these parameters have been reported as 250.0 μg/l and 0.66, respectively (Marshall, 1980). The average TP concentration of 1.0 mg/l for the column study runoff samples directly indicates a total phosphorus concentration of 1000 μg/l. These values are plotted in Figure V-5 along with concentrations that reflect treatment by sedimentation. However, as illustrated in Figure V-5, the 22.4 percent reduction in total phosphorus concentration due to settling is not adequate for improving the trophic state of Lake Eola.

For Lake Eola to be classified as mesotrophic by Vollenweider's model, the phosphorus loadings according to Marshall (1980) and the column study would require reductions of 67 and 92 percent, respectively. A similar lake classification by the Dillon model would be possible if the total phosphorus loading reported by Marshall (1980) was diminished by approximately 69 percent. The column study loading would require a 92 percent reduction. Mesotrophic status for Lake Eola occurs, according to the Larsen-Mercier model, when the total phosphorus concentrations of Marshall (1980) and the column study are reduced by nearly 77 and 94 percent, respectively. Thus, it is readily apparent from the column study results and the regression analysis, that plain sedimentation will not achieve the degree of removal necessary to significantly improve the trophic status of Lake Eola.

CHAPTER VI

CONCLUSIONS

The removal data that were presented in Chapter IV, and the data analysis of Chapter V provide a formidable basis for the evaluation of sedimentation/detention as a treatment alternative for urban stormwater runoff. Throughout the column studies, many removal trends were identified and the following conclusions appear to be appropriate.

1. The quality of urban stormwater runoff is extremely variable. Consequently, the use of column studies is necessary to assess the water quality effects of sedimentation.

2. A significant fraction of the total suspended solids that were contained in Lake Eola stormwater were of a non-discrete variety.

3. Sedimentation provides significant treatment of suspended solids in urban stormwater. Removal efficiencies that approached 50 percent were shown for Lake Eola runoff.

4. Moderate removals of NH_3-N, TKN, COD, and TOC will occur as settling progresses. These parameters experienced enhanced removals when total suspended solids were high in concentration.

5. Significant phosphorus removals will occur during the sedimentation of urban stormwater. Removal efficiencies for Lake Eola stormwater approached 30 percent.

6. Plain sedimentation is an ineffective means of treatment for heavy metals excluding lead. Nearly 20 percent of the lead in Lake Eola stormwater was removed by settling.

7. Regression equations are useful for describing the removal behavior of pollutants as a function of time and settling velocity. In addition, these equations can be used for the design of stormwater settling facilities.

8. Isoconcentration lines are helpful in predicting the performance of a sedimentation or detention basin.

9. The phosphorus removals that were achieved during the column studies were not complete enough to produce an improvement in trophic state for Lake Eola. According to the trophic state models of Vollenweider, Dillon and Larsen-Mercier, the eutrophic state of Lake Eola will persist if stormwater is settled and subsequently discharged to the lake.

APPENDIX A

TABLE A-1

COMPOSITE SAMPLE AND HYDROGRAPH DATA FOR COLUMN STUDY NUMBER 1*

Sample #	Volume Collected (Gal)	Time to Fill (Min)	Flow (gpm)	Elapsed Time From Storm Start (Min)	Storm Volume		Column Volume (liters)	
					Gallon	Percent	Theory	Actual
1	4	2.27	1.76	3.0	5.28	0.06	0.08	0.08
2	4	0.40	10.0	6.0	30.0	0.35	0.47	0.47
3	4	0.56	7.14	7.0	7.14	0.08	0.11	0.11
4	4	0.25	16.0	8.5	24.0	0.28	0.38	0.38
5	4	0.22	18.18	9.5	18.2	0.21	0.28	0.28
6	4	0.21	19.05	12.0	47.6	0.55	0.73	0.73
7	4	0.10	40.0	14.0	80.0	0.93	1.24	1.24
8	4	0.12	33.3	18.0	133.0	1.55	2.06	2.06
9	4	0.06	66.7	21.0	200.0	2.33	3.11	3.11
10	4	0.04	100.0	26.0	500.0	5.82	7.77	7.77
11	4	0.035	114.3	32.0	686.0	7.98	10.64	10.64
12	4	0.04	100.0	41.0	900.0	10.47	13.97	13.97
13	4	0.05	80.0	48.0	560.0	6.51	8.69	8.69
14	4	0.05	80.0	53.0	400.0	4.65	6.20	6.20
15	4	0.06	66.7	64.0	733.0	8.53	11.38	11.38
16	4	0.05	80.0	77.0	560.0	6.51	8.7 *	10.4
17	4	0.04	100.0	89.0	1200.0	13.96	18.6 *	15.14
18	4	0.048	83.3	106.0	466.0	5.42	7.2 *	9.9
19	4	0.12	33.3	120.0	466.0	5.42	7.2	7.2
20	4	0.13	30.8	147.0	832.0	9.68	12.91	12.91
21	4	0.15	26.7	167.0	534.0	6.21	8.29	8.29
22	4	0.32	12.5	184.0	213.0	2.48	3.31	3.31

* Sample Location: School　　Storm Date: 4/5/79

TABLE A-2

COMPOSITE SAMPLE AND HYDROGRAPH DATA FOR COLUMN STUDY NUMBER 2*

Sample #	Volume Collected (Gal)	Time to Fill (Min)	Flow (gpm)	Elapsed Time From Storm Start (Min)	Storm Volume		Column Volume (liters)	
					Gallon	Percent	Theory	Actual
1	4	3.67	1.09	3.67	4.0	0.95	1.16	1.2
2	4	1.65	2.42	5.82	5.2	1.24	1.52	1.5
3	4	2.83	1.41	11.32	7.8	1.86	2.27	2.3
4	4	2.20	1.82	19.17	14.3	3.40	4.16	4.2
5	4	2.81	1.42	22.97	5.4	1.28	1.57	1.6
6	4	2.89	1.38	26.07	4.3	1.02	1.25	1.2
7	4	6.90	0.58	42.7	9.6	2.28	2.79	2.8
8	4	1.90	2.10	44.8	4.3	1.02	1.25	1.2
9	4	1.70	2.35	48.5	8.7	2.07	2.53	2.5
10	4	1.00	4.00	50.9	9.6	2.28	2.79	2.8
11	4	0.70	5.71	57.7	5.1	1.21	1.48	1.5
12	4	0.90	4.44	53.1	5.8	1.38	1.69	1.7
13	4	0.30	13.33	54.8	21.3	5.07	6.20	6.2
14	4	2.20	1.82	57.2	4.6	1.09	1.33	1.3
15	4	1.10	3.63	61.2	14.5	3.45	4.22	4.2
16	4	0.35	11.43	75.6	22.6	5.38	6.58	11.3
17	4	0.30	13.33	77.6	23.9	5.69	6.96	14.4
18	4	0.25	16.0	79.4	28.8	6.85	8.38	15.1
19	4	0.25	16.0	81.5	33.6	7.99	9.77	15.1
20	4	0.30	13.33	90.7	122.0	29.02	35.49	15.1
21	4	0.75	5.33	103.0	65.0	15.46	18.91	15.1

* Sample Location: George Stuart Storm Date: 4/25/79

TABLE A-3

COMPOSITE SAMPLE AND HYDROGRAPH DATA FOR COLUMN STUDY NUMBER 3*

Sample #	Volume Collected (Gal)	Time to Fill (Min)	Flow (gpm)	Elapsed Time From Storm Start (Min)	Storm Volume		Column Volume (liters)	
					Gallon	Percent	Theory	Actual
1	4	1.08	3.70	1.08	4.00	0.25	0.31	0.31
2	4	0.63	5.88	5.33	24.99	1.57	1.92	1.92
3	4	0.52	7.69	9.50	32.08	2.01	2.46	2.46
4	4	0.23	17.33	13.75	73.65	4.62	5.65	5.65
5	4	0.12	33.33	18.0	141.53	8.88	10.86	10.86
6	4	0.12	33.33	22.25	141.53	8.88	10.86	10.86
7	4	0.12	33.33	26.08	141.53	8.88	10.86	10.86
8	4	0.12	33.33	38.33	141.53	8.88	10.86	10.86
9	4	0.12	33.33	51.08	141.53	8.88	10.86	10.86
10	4	0.20	20.0	60.08	180.00	11.29	13.81	13.81
11	4	0.27	14.81	64.08	59.24	3.72	4.55	4.55
12	4	0.22	18.13	67.08	54.39	3.41	4.17	4.17
13	4	0.23	17.33	71.08	69.32	4.35	5.32	5.32
14	4	0.22	18.13	75.08	72.52	4.55	5.56	5.56
15	4	0.28	14.29	81.08	57.16	3.59	4.39	4.39
16	4	0.37	10.81	86.08	54.05	3.39	4.15	4.15
17	4	0.45	8.89	91.08	44.45	2.79	3.41	3.41
18	4	0.52	7.69	96.08	38.45	2.41	2.95	2.95
19	4	0.82	4.88	101.08	24.40	1.53	1.87	1.87
20	4	0.78	5.13	106.08	26.65	1.61	1.97	1.97
21	4	0.87	4.60	111.08	23.00	1.44	1.76	1.76
22	4	0.82	4.88	116.08	24.40	1.53	1.87	1.87
23	4	0.82	4.88	121.08	24.40	1.53	1.87	1.87

* Sample Location: Lake Eola, West Storm Date: 5/24/79

TABLE A-4

COMPOSITE SAMPLE AND HYDROGRAPH DATA FOR COLUMN STUDY NUMBER 4*

Sample #	Volume Collected (Gal)	Time To Fill (Min)	Flow (gpm)	Elapsed Time From Storm Start (Min)	Storm Volume		Column Volume (liters)	
					Gallon	Percent	Theory	Actual
1	4	3.5	1.14	3.5	4.00	0.39	0.47	0.47
2	4	0.33	12.27	3.88	4.67	0.45	0.55	0.55
3	4	0.17	23.53	4.13	5.88	0.57	0.70	0.70
4	4	0.13	30.77	4.35	6.77	0.66	0.80	0.80
5	4	0.07	57.14	4.50	8.57	0.83	1.02	1.02
6	5	0.05	100.00	4.60	10.00	0.97	1.19	1.19
7	5	0.07	71.43	4.75	10.71	1.04	1.27	1.27
8	4	0.05	80.00	4.88	10.40	1.01	1.23	1.23
9	5	0.07	71.43	5.03	10.71	1.04	1.27	1.27
10	4	0.05	80.00	5.29	20.80	2.08	2.54	2.54
11	4	0.05	80.00	5.41	10.40	1.04	1.27	1.27
12	4	0.05	80.00	5.53	9.60	0.93	1.14	1.14
13	5	0.05	100.00	5.65	12.00	1.16	1.42	1.42
14	4	0.05	80.00	5.77	9.60	0.93	1.27	2.20
15	4	0.05	80.00	5.99	17.60	1.86	2.54	15.14
16	4	0.05	80.00	12.06	485.60	47.12	57.62	15.14
17	4	0.05	80.00	12.19	10.40	1.04	1.27	15.14
18	4	0.05	80.00	12.32	10.40	1.04	1.27	15.14
19	4	0.07	57.14	17.47	294.27	28.55	34.92	15.14
20	4	0.60	6.67	28.79	75.50	7.33	8.96	15.14
21	4	0.87	4.60	29.39	2.76	0.27	0.33	15.14

* Sample Location: Lake Eola, North Storm Date: 6/22/79

TABLE A-5

COMPOSITE SAMPLE AND HYDROGRAPH DATA FOR COLUMN STUDY NUMBER 5*

Sample #	Volume Collected (Gal)	Time to Fill (Min)	Flow (gpm)	Elapsed Time From Storm Start (Min)	Storm Volume		Column Volume (liters)	
					Gallon	Percent	Theory	Actual
1	4	2.94	1.361	5	9.02	0.5	0.6	0.6
2	4	1.78	2.247	7	5.61	0.3	0.4	0.4
3	4	1.19	3.361	11	11.84	0.6	0.7	0.7
4	4	1.56	2.564	14	6.27	0.3	0.4	14.2
5**	4	2.47	1.619	17	70.61	3.6	4.4	---
6	4	0.088	45.45	24	428.3	21.8	26.8	13.0
7**	4	0.052	76.92	25	81.56	4.2	5.2	---
8	5	0.058	86.21	26	80.42	4.1	5.0	14.5
9	5	0.067	74.63	28	150.1	7.6	9.3	15.0
10	4	0.053	75.47	29	77.7	4.0	4.9	9.7
11	4	0.050	80.00	31	149.0	7.6	9.3	9.3
12**	4	0.058	68.97	33	138.0	7.0	8.6	---
13	4	0.058	68.97	34	61.9	3.2	3.9	12.6
14	4	0.073	54.79	35	51.5	2.6	3.2	3.2
15	4	0.083	48.19	37	81.5	4.1	5.0	1.0
16	4	0.120	33.33	38	40.2	2.0	2.5	1.0
17	4	0.085	47.06	39	41.4	2.1	2.6	1.0
18	4	0.112	35.71	40	34.8	1.8	2.2	1.0
19	4	0.118	33.90	41	33.6	1.7	2.1	1.0
20	4	0.120	33.33	42	31.0	1.6	2.0	1.0
21	4	0.140	28.57	44	48.4	2.5	3.1	1.0
22	4	0.202	19.80	47	55.2	2.8	3.4	1.0
23	4	0.235	17.02	52	156.0	7.9	9.7	1.0
24	4	0.088	45.45	57	117.0	6.0	7.4	1.0
25	4	2.472	1.62	59.5	4.0	0.2	0.2	1.0

* Sampling Location: School Storm Date: 6/27/79

** Used for Hydrograph Analysis only

TABLE A-6

COMPOSITE SAMPLE AND HYDROGRAPH DATA FOR COLUMN STUDY NUMBER 6*

Sample #	Volume Collected (Gal)	Time To Fill (Min)	Flow (gpm)	Elapsed Time From Storm Start (Min)	Storm Volume		Column Volume (liters)	
					Gallon	Percent	Theory	Actual**
1	4	1.825	2.19	1.83	4.0	0.33	0.4	15.1
2	4	0.05	80	4.88	125.3	10.24	12.5	15.1
3	4	0.05	80	7.93	244.0	19.95	24.4	15.1
4	4	0.05	80	9.98	164.0	13.41	16.4	15.1
5	3	0.07	45	11.05	129.4	10.58	12.9	15.1
6	5	0.07	71.4	13.12	120.5	9.85	12.4	15.1
7	4	0.05	80	15.17	155.2	12.69	15.5	15.1
8	5	0.07	71.4	17.24	156.7	12.81	15.7	4.5
9	4	0.13	30.0	18.37	57.3	4.68	5.7	4.5
10	1	0.07	15	20.44	46.6	3.81	4.7	3.8
11	1	0.04	24	21.48	20.3	1.66	2.03	3.8

* Sample Location: Lake Eola, North   Storm Date: 7/8/79

** Catch basin overflowed and representative sampling was not possible.

TABLE A-7

COMPOSITE SAMPLE AND HYDROGRAPH DATA FOR COLUMN STUDY NUMBER 7*

Sample #	Volume Collected (Gal)	Time To Fill (Min)	Flow (gpm)	Elapsed Time From Storm Start (Min)	Storm Volume		Column Volume (liters)	
					Gallon	Percent	Theory	Actual
1	5	3.10	1.61	3.10	5.0	0.15	0.19	0.19
2	5	0.25	20.0	6.25	34.0	1.05	1.28	1.28
3	4	0.08	50.0	11.33	117.8	5.49	6.72	6.72
4	4	0.07	57.14	18.40	378.8	11.7	14.31	14.31
5	4	0.10	40.0	26.50	393.4	12.15	14.86	14.86
6	4	0.10	40.0	33.50	284.0	8.77	10.73	10.73
7	4	0.10	40.0	39.70	244.0	7.54	9.21	9.21
8	4	0.12	33.3	50.82	407.6	12.59	15.40	15.40
9	4	0.18	22.2	64.00	365.8	11.30	13.82	13.82
10	4	0.20	20.0	71.20	151.9	4.69	5.74	5.74
11	4	0.19	21.1	80.39	188.8	5.83	7.13	7.13
12	4	0.27	14.8	84.66	76.7	2.37	2.89	2.89
13	4	0.27	14.8	87.95	48.7	1.50	1.84	1.84
14	4	0.27	14.8	93.32	79.5	2.46	3.00	3.00
15	4	0.34	11.8	98.66	71.0	2.19	2.68	2.68
16	4	0.37	11.8	105.03	75.2	2.32	2.84	2.84
17	4	0.47	8.5	117.50	126.6	3.91	4.78	4.78
18	4	0.44	9.1	120.94	30.3	0.94	1.14	1.14
19	4	0.46	8.7	124.40	30.8	0.95	1.16	1.16
20	4	0.44	9.1	128.44	36.0	1.11	1.36	1.36
21	4	0.46	8.7	131.90	30.8	0.95	1.16	1.16

* Sample Location: George Stuart Storm Date: 7/12/79

APPENDIX B

TABLE B-1

GENERAL WATER QUALITY DATA FOR COLUMN STUDY NUMBER 1*

Port (ft)	Time (min)	Vel (ft/min)	TSS (mg/l)	VSS (mg/l)	NVSS (mg/l)	COD (mg/l)	TKN-N (mg/l)	NH_3-N (mg/l)	TOC-C (mg/l)	TP-P (mg/l)
1.17	0	----	154	136	18		17.6	2.8	515	3.3
3.17	0	----	142	126	16		17.9	1.7	505	3.3
4.50	0	----	120	108	12		17.4	1.7	540	2.9
1.17	5	0.23	112	102	10		18.2	1.4	524	2.1
3.17	5	0.63	110	98	12		19.0	1.7	514	2.8
4.50	5	0.90	160	138	22		18.8	1.4	496	3.3
1.17	10	0.12	728	716	12		24.6	1.7	496	2.8
3.17	10	0.32	176	152	20		19.9	0.9	511	2.8
4.50	10	0.45	124	112	12		----	1.7	469	1.8
1.17	15	0.08	106	102	4		18.8	0.9	596	1.9
3.17	15	0.21	142	124	18		21.0	1.4	564	2.2
4.50	15	0.30	172	158	14		17.6	1.1	446	2.2
1.17	30	0.04	136	119	17		14.5	1.4	412	2.0
3.17	30	0.11	168	104	52		16.5	1.7	419	2.1
4.50	30	0.15	132	120	12		17.9	0.6	392	2.1
1.17	60	0.02	76	82	0		17.9	1.7	408	1.9
3.17	60	0.05	208	176	32		16.5	1.7	488	1.9
4.50	60	0.08	128	110	18		16.8	2.0	450	2.2
1.17	120	0.01	114	96	18		19.9	0.9	362	1.9
3.17	120	0.03	144	116	28		19.3	1.4	391	2.5
4.50	120	0.04	132	128	4		17.4	1.1	405	1.2

* Sample Location: School   Storm Date: 4/5/79

TABLE B-2

METALS DATA FOR COLUMN STUDY NUMBER 1*

Port (ft)	Time (min)	Vel. (ft/min)	Zn (μg/l)	Cd (μg/l)	As (μg/l)	Ni (μg/l)	Cu (μg/l)	Mg (μg/l)	Fe (μg/l)	Pb (μg/l)	Ca (mg/l)	Cr (μg/l)
1.17	0	----	945	12	110	138	196		2730	1580	53.0	80
3.17	0	----		19			187	6325	3650	2240	49.2	73
4.50	0	----	935	23	137	79	188		3605	1920	53.0	98
1.17	5	0.23		15	88		149	4970	1830	1555	40.6	59
3.17	5	0.63	835	11	37	54	144		2910	1770	53.0	48
4.50	5	0.90	975	15	89	72	175		3555	2040	52.5	67
1.17	10	0.12	750	3	240	67	168		2675	1780	60.1	64
3.17	10	0.32	745	9	118	59	134		2320	1480	49.8	53
4.50	10	0.45	785	9	45	63	156		2195	1440	51.0	60
1.17	15	0.08	780	11	106	83	128	6300	2030	1400	48.7	63
3.17	15	0.21		10			178	6250	2365	1715	46.2	59
4.50	15	0.30	820	6	44	75	182		3410	2835	60.1	66
1.17	30	0.04	700	4	12	68	154		2085	1510	56.6	67
3.17	30	0.11	685	3	0	55	161		2270	1605	58.1	48
4.50	30	0.15	725	11	17	54	130	6200	2100	1370	48.6	57
1.17	60	0.02	750	13	29	53	140	6150	1525	1150	47.6	51
3.17	60	0.05	720	8	111	635	141		4715	1530	58.1	850
4.50	60	0.08	755	16	59	61	222	6250	2100	1460	48.8	58
1.17	120	0.01		17			147	4940	1700	1500	39.7	53
3.17	120	0.03	785	11	0	64	163		2700	1815	58.6	62
4.50	120	0.04	795	19	74	63	137	6200	1865	1345	48.3	53

* Sample Location: School   Storm Date: 4/5/79

TABLE B-3

GENERAL WATER QUALITY DATA FOR COLUMN STUDY NUMBER 2*

Port (ft)	Time (min)	Vel. (ft/min)	TSS (mg/l)	VSS (mg/l)	NVSS (mg/l)	COD (mg/l)	TKN-N (mg/l)	NH_3-N (mg/l)	TOC-C (mg/l)	TP-P (mg/l)
1.17	0	----	67.5	46	21.5	212	1.68	0	53	0.26
3.17	0	----	77	47	30.0	263	1.40	0	77	0.33
4.50	0	----	69	39	30.0	203	0.98	0	53	0.32
1.17	5	0.23	68	38	30.0	236	1.54	0	46	0.27
3.17	5	0.63	81	49	32.0	278	1.12	0	60	0.34
4.50	5	0.90	68	36	32.0	334	1.26	0	72	0.38
1.17	10	0.12	60	36	24.0	226	0.98	0	46	0.25
3.17	10	0.32	66	40	26.0	263	1.54	0	64	0.30
4.50	10	0.45	72	36	36.0	305	0.98	0	76	0.35
1.17	15	0.08	63	33	30.0	259	1.26	0	66	0.23
3.17	15	0.21	57	35	22.0	268	0.84	0	69	0.30
4.50	15	0.30	63	35	28.0	251	0.98	0	66	0.31
1.17	30	0.04	45	24	20.0	188	----	0	51	0.19
3.17	30	0.11	55	29	26.0	249	0.42	0	67	0.18
4.50	30	0.15	63	33	30.0	221	1.96	0	53	0.21
1.17	60	0.02	42	22	20.0	203	1.96	0	47	0.20
3.17	60	0.05	51	26	25.0	179	0.98	0	43	0.25
4.50	60	0.08	50	30	20.0	249	1.12	0	38	0.22
1.17	120	0.01	84	28	60.0	146	1.25	0	41	0.21
3.17	120	0.03	49	27	22.0	287	1.40	0	77	0.23
4.50	120	0.04	45	25	20.0	249	0.84	0	60	0.25

* Sample Location: George Stuart Storm Date: 4/25/79

TABLE B-4

METALS DATA FOR COLUMN STUDY NUMBER 2*

Port (ft)	Time (min)	Vel. (ft/min)	Zn (μg/l)	Cd (μg/l)	As (μg/l)	Ni (μg/l)	Cu (μg/l)	Mg (μg/l)	Fe (μg/l)	Pb (μg/l)	Ca (mg/l)	Cr (μg/l)
1.17	0	----	387	8	175	61	111		1520	655	61.0	61
3.17	0	----	540	24	163	56	94		1840	870	66.0	67
4.50	0	----	439	10	247	60	87		1380	715		58
1.17	5	0.23	460	5	175	92	97		1520	765	64.0	64
3.17	5	0.63	333	46	705	63	164	2858	1853	932		38
4.50	5	0.90	586	41	748	70	180	2930	2212	1010		54
1.17	10	0.12	303	48	799	86	171	2882	1634	789		39
3.17	10	0.32	418	34	639	67	178	2900	3750	900		68
4.50	10	0.45	434	43	635	73	184	3055	2175	1020		54
1.17	15	0.08	363	110	1222	145	346	2965	2379	1119		136
3.17	15	0.21	366	39	587	60	156	2765	1495	786		36
4.50	15	0.30	338	32	432	56	159	2825	1905	810		36
1.17	30	0.04	232	28	560	56	148	2775	1195	665		40
3.17	30	0.11	355	26	284	58	144	2905	1545	815		39
4.50	30	0.15	334	24	376	76	163	2985	1540	770		39
1.17	60	0.02	332	2	236	46	90		954	547	63.2	67
3.17	60	0.05	197	48	820	65	147	2565	1270	640		32
4.50	60	0.08	358	36	520	63	161	2870	1200	680		37
1.17	120	0.01	157	24	426	45	124	2546	781	471		24
3.17	120	0.03	237	43	740	55	145	2625	1205	670		34
4.50	120	0.04	263	26	400	55	144	2840	1230	675		41

* Sample Location: George Stuart Storm Date: 4/25/79

TABLE B-5

GENERAL WATER QUALITY DATA FOR COLUMN STUDY NUMBER 3*

Port (ft)	Time (min)	Vel. (ft/min)	TSS (mg/l)	VSS (mg/l)	NVSS (mg/l)	COD (mg/l)	TKN-N (mg/l)	NH_3-N (mg/l)	TOC-C (mg/l)	TP-P (mg/l)
1.17	0	----	19	3	16	58.4	1.12	0.34	----	0.17
3.17	0	----	61	43	18	54.5	1.12	0.22	19.8	0.12
4.50	0	----	79	15	64	58.4	1.46	0.22	20.0	0.13
1.17	5	0.23	62	12	50	87.6	0.78	0.00	14.0	0.16
3.17	5	0.63	47	33	14	48.6	1.12	0.34	19.2	0.28
4.50	5	0.90	69	9	60	38.9	1.34	0.52	16.6	0.20
1.17	10	0.12	16	16	0	58.4	1.23	0.34	7.6	0.07
3.17	10	0.32	23	23	0	48.6	0.90	0.22	----	0.76
4.50	10	0.45	72	10	62	54.5	1.46	0.45	16.0	0.20
1.17	15	0.08	36	10	26	40.9	1.01	0.34	14.4	0.14
3.17	15	0.21	55	9	46	48.6	0.22	0.22	10.5	0.13
4.50	15	0.30	12	10	2	99.2	1.34	0.45	17.6	0.11
1.17	30	0.04	45	3	42	48.6	0.90	0.34	12.5	0.14
3.17	30	0.11	50	10	40	58.4	0.90	0.34	11.2	----
4.50	30	0.15	45	5	40	38.9	1.12	0.34	18.8	0.25
1.17	60	0.02	20	0	20	38.9	0.56	0.11	11.6	0.20
3.17	60	0.05	21	21	0	48.6	0.39	0.00	11.7	0.23
4.50	60	0.08	55	5	50	48.6	1.68	0.22	20.7	0.14
1.17	120	0.01	1	1	0	29.2	2.02	0.22	10.4	0.07
3.17	120	0.03	51	1	50	38.9	1.34	0.22	11.0	0.05
4.50	120	0.04	15	13	2	48.6	1.01	0.34	10.1	0.05

* Sample Location: Lake Eola, West   Storm Date: 5/24/79

TABLE B-6

METALS DATA FOR COLUMN STUDY NUMBER 3*

Port (ft)	Time (min)	Vel. (ft/min)	Zn (μg/l)	Cd (μg/l)	As (μg/l)	Ni (μg/l)	Cu (μg/l)	Mg (μg/l)	Fe (μg/l)	Pb (μg/l)	Ca (mg/l)	Cr (μg/l)
1.17	0	----	415	123	75	31	66	470	915	219		29
3.17	0	----	414	30			80	650	1260	700	20.9	46
4.50	0	----	81	4	120	12	21	97	211	29		5
1.17	5	0.23										
3.17	5	0.63	137	15	24	57	69	405	705	162		22
4.50	5	0.90	585	20	135	74	56	885	1315	408	24.6	63
1.17	10	0.12	257	32	985	276	66	610	930	625	16.5	47
3.17	10	0.32	408	12	66	37	43	795	1130	840	21.5	50
4.50	10	0.45	494	16			63	705	1100	640	19.3	63
1.17	15	0.08	351	17	37	33	42	730	860	279	19.2	33
3.17	15	0.21	595	13	76	38	45	745	925	335	19.9	45
4.50	15	0.30	600	6	184	41	52		1245	451	27.8	56
1.17	30	0.04	184	67	1005	63	130	815	1145	435		31
3.17	30	0.11	402	7	0	35	61		1040	369	24.2	44
4.50	30	0.15	394	4	11	39	52		1070	436	24.9	61
1.17	60	0.02	366	15	9	35	42	675	595	223	15.8	34
3.17	60	0.05	385	17	125	34	49	750	825	288	19.0	41
4.50	60	0.08	157	54	715	78	123	775	945	451		28
1.17	120	0.01	272	23			75	695	855	565	15.1	43
3.17	120	0.03	285	16	20	50	42	715	765	283	17.9	48
4.50	120	0.04	241	13			64	710	955	510	15.7	53

* Sample Location: Lake Eola, West Storm Date: 5/24/79

TABLE B-7

GENERAL WATER QUALITY DATA FOR COLUMN STUDY NUMBER 4*

Port (ft)	Time (min)	Vel. (ft/min)	TSS (mg/l)	VSS (mg/l)	NVSS (mg/l)	COD (mg/l)	TKN-N (mg/l)	NH_3-N (mg/l)	TOC-C (mg/l)	TP-P (mg/l)
1.17	0	----	50	36	14	128	3.92	0.99	22.5	0.99
3.17	0	----	102	64	38	138	2.38	0.76	44.4	0.92
4.50	0	----	78	48	30	118	2.58	0.82	21.5	1.01
1.17	5	0.23	46	28	18	118	2.69	0.87	25.6	0.82
3.17	5	0.63	68	38	30	130	2.46	0.67	23.7	0.84
4.50	5	0.90	48	32	16	132	2.80	0.70	23.8	0.71
1.17	10	0.12	38	28	10	118	2.35	0.67	27.8	0.71
3.17	10	0.32	42	26	16	118	2.58	0.67	21.7	0.84
4.50	10	0.45	38	30	8	89	2.58	0.70	20.9	0.94
1.17	15	0.08	36	20	12	108	1.68	0.67	19.8	0.76
3.17	15	0.21	38	26	12	108	1.90	0.70	24.5	0.78
4.50	15	0.30	40	22	18	93	2.24	0.73	26.6	0.59
1.17	30	0.04	24	16	8	89	2.69	0.93	21.8	0.79
3.17	30	0.11	34	26	8	118	2.69	0.65	23.8	0.83
4.50	30	0.15	24	18	6	79	2.46	0.76	27.7	0.81
1.17	60	0.02	20	16	4	89	2.02	0.67	17.3	0.84
3.17	60	0.05	26	18	8	99	1.79	0.62	21.3	0.86
4.50	60	0.08	23	15	8	69	2.58	0.56	24.3	0.82
1.17	120	0.01	12	8	4	73	2.24	0.53	25.0	0.70
3.17	120	0.03	26	20	6	85	2.24	0.67	21.3	0.86
4.50	120	0.04	23	15	8	63	2.58	0.67	20.6	0.81

* Sample Location: Lake Eola, North Storm Date: 6/22/79

TABLE B-8

METALS DATA FOR COLUMN STUDY NUMBER 4*

Port (ft)	Time (min)	Vel. (ft/min)	Zn (μg/l)	Cd (μg/l)	As (μg/l)	Ni (μg/l)	Cu (μg/l)	Mg (μg/l)	Fe (μg/l)	Pb (μg/l)	Ca (mg/l)	Cr (μg/l)
1.17	0	----	818	73	83	39	68	915	899	280	24.9	37
3.17	0	----	1050	39	50	23	58	949	853	292	26.7	34
4.50	0	----	536	19	0	20	55	832	755	261	22.0	31
1.17	5	0.23	324	19	37	20	64	822	794	267	21.8	28
3.17	5	0.63	460	11	48	20	53	789	743	252	21.4	26
4.50	5	0.90	718	10	0	19	53	817	749	258	22.5	33
1.17	10	0.12	467	16	74	27	72	846	810	273	22.5	29
3.17	10	0.32	768	13	2	59	72	850	967	300	24.5	35
4.50	10	0.45	367	10	83	20	48	800	820	272	21.6	36
1.17	15	0.08	599	19	0	44	76	875	874	280	22.8	34
3.17	15	0.21	590	10	31	20	49	831	878	273	22.6	34
4.50	15	0.30	1080	13	55	28	59	1110	1040	314	30.0	42
1.17	30	0.04	819	18	13	31	77	923	764	259	24.2	35
3.17	30	0.11	1130	13	18	19	56	1040	887	282	29.0	34
4.50	30	0.15	434	12	0	33	53	857	931	269	22.4	41
1.17	60	0.02	1060	15	0	18	46	844	694	237	23.5	25
3.17	60	0.05	884	11	64	19	54	826	770	262	22.6	33
4.50	60	0.08	481	11	104	25	48	836	852	257	22.2	35
1.17	120	0.01	344	15	22	15	48	746	566	194	19.4	24
3.17	120	0.03	371	10	88	19	56	802	700	245	21.4	31
4.50	120	0.04	477	11	29	34	52	805	844	236	21.1	37

* Sample Location: Lake Eola, North Storm Date: 6/22/79

TABLE B-9

GENERAL WATER QUALITY DATA FOR COLUMN STUDY NUMBER 5*

Port (ft)	Time (min)	Vel. (ft/min)	TSS (mg/l)	VSS (mg/l)	NVSS (mg/l)	COD (mg/l)	TKN-N (mg/l)	NH_3-N (mg/l)	TOC-C (mg/l)	TP-P (mg/l)
1.17	0	----	160	88	72	335	0.78	0.13	39.3	1.42
3.17	0	----	319	155	164	216	1.01	0.13	31.0	1.70
4.50	0	----	302	146	156	216	1.12	0.16	16.8	1.44
1.17	5	0.23	118	60	58	151	1.01	0.10	31.0	1.33
3.17	5	0.63	147	71	76	162	1.46	0.15	30.9	1.37
4.50	5	0.90	174	90	84	171	1.23	0.16	23.4	1.48
1.17	10	0.12	110	54	56	149	0.78	0.12	27.6	1.11
3.17	10	0.32	142	74	68	151	1.01	0.13	33.0	1.30
4.50	10	0.45	133	67	66	195	1.01	0.16	27.4	1.38
1.17	15	0.08	55	25	30	140	1.12	0.12	29.3	0.90
3.17	15	0.21	144	70	74	184	1.46	0.13	34.5	1.42
4.50	15	0.30	99	47	52	151	1.12	0.13	26.3	1.48
1.17	30	0.04	43	23	20	129	1.23	0.12	28.3	0.82
3.17	30	0.11	53	27	26	149	1.34	0.12	21.8	0.99
4.50	30	0.15	51	23	28	141	1.34	0.15	22.9	0.96
1.17	60	0.02	43	27	16	128	1.23	0.13	24.1	0.79
3.17	60	0.05	46	24	22	169	1.23	0.12	20.8	0.88
4.50	60	0.08	51	27	26	140	1.23	0.13	20.0	0.92
1.17	120	0.01	---	--	--	216	1.46	0.18	24.3	0.78
3.17	120	0.03	46	38	8	173	1.23	0.10	17.4	0.86
4.50	120	0.04	56	28	28	130	1.34	0.13	11.6	0.95

* Sample Location: School   Storm Date: 6/27/79

TABLE B-10

METALS DATA FOR COLUMN STUDY NUMBER 5*

Port (ft)	Time (min)	Vel. (ft/min)	Zn (μg/l)	Cd (μg/l)	As (μg/l)	Ni (μg/l)	Cu (μg/l)	Mg (μg/l)	Fe (μg/l)	Pb (μg/l)	Ca (mg/l)	Cr (μg/l)
1.17	0	----	758	53	1226	64	117	2874	2060	615	29.4	125
3.17	0	----	770	23	1143	19	39	2764	1440	632	30.7	44
4.50	0	----	487	7	1035	17	38	2588	1290	628	32.0	32
1.17	5	0.23	294	15	1101	20	36	2335	1370	596	29.0	40
3.17	5	0.63	339	11	1101	23	58	2599	1860	621	30.1	45
4.50	5	0.90	1064	9	1572	34	61	3590	1910	848	42.1	46
1.17	10	0.12	791	14	1090	108	52	2588	2500	586	31.6	161
3.17	10	0.32	433	10	1016	20	42	1707	1060	570	28.5	31
4.50	10	0.45	756	12	1132	59	63	2313	1420	596	29.8	41
1.17	15	0.08	1654	15	1111	47	34	2170	1530	586	32.9	77
3.17	15	0.21	463	11	1258	29	39	2225	1220	581	28.9	46
4.50	15	0.30	399	9	1258	39	52	1949	1030	580	28.4	44
1.17	30	0.04	276	10	745	23	45	2519	1412	582	27.3	53
3.17	30	0.11	2162	7	985	30	42	2720	1462	603	32.4	49
4.50	30	0.15	689	7	765	26	43	2106	1242	597	29.0	50
1.17	60	0.02	1562	7	615	30	64	2476	1322	529	30.4	46
3.17	60	0.05	1962	7	835	77	37	2550	1752	608	37.0	86
4.50	60	0.08	426	5	645	25	67	2360	1182	570	27.5	43
1.17	120	0.01	2732	77	745	37	51	1767	941	505	42.7	43
3.17	120	0.03	1522	7	755	46	38	2074	1502	547	33.7	70
4.50	120	0.04	1422	13	775	34	50	2296	1162	562	33.1	60

* Sample Location: School Storm Date: 6/27/79

TABLE B-11

GENERAL WATER QUALITY DATA FOR COLUMN STUDY NUMBER 6*

Port (ft)	Time (min)	Vel. (ft/min)	TSS (mg/l)	VSS (mg/l)	NVSS (mg/l)	COD (mg/l)	TKN-N (mg/l)	NH_3-N (mg/l)	TOC-C (mg/l)	TP-P (mg/l)
1.17	0	----	318	214	104	290	5.250	.16		.800
3.17	0	----	238	158	80	260	3.240	.15		.836
4.50	0	----	524	348	176	260	4.620	.15		1.015
1.17	5	0.23	112	70	42	98	2.590	.15		.747
3.17	5	0.63	134	90	44	150	2.730	.16		.783
4.50	5	0.90	172	102	70	230	2.870	.13		.926
1.17	10	0.12	64	38	26	120	1.890	.11		.664
3.17	10	0.32	80	46	34	80	2.660	.13		.765
4.50	10	0.45	128	88	40	110	2.17	.15		.789
1.17	15	0.08	48	26	22	50	1.75	.15		.604
3.17	15	0.21	74	44	30	90	1.82	.15		.729
4.50	15	0.30	117	49	68	---	1.47	.16		.717
1.17	30	0.04	35	19	16	100	1.05	.13		.473
3.17	30	0.11	48	22	26	50	0.77	.15		.568
4.50	30	0.15	56	32	24	60	1.12	.15		.676
1.17	60	0.02	26	14	12	100	0.63	.15		.425
3.17	60	0.05	37	19	18	50	0.84	.11		.556
4.50	60	0.08	36	---	---	54	0.91	.16		.598
1.17	120	0.01	22	10	12	60	0.84	.10		.372
3.17	120	0.03	27	17	10	44	0.84	.16		.491
4.50	120	0.04	40	22	18	60	0.70	.15		.568

* Sample Location: Lake Eola, North Storm Date: 7/8/79

TABLE B-12

METALS DATA FOR COLUMN STUDY NUMBER 6*

Port (ft)	Time (min)	Vel. (ft/min)	Zn (μg/l)	Cd (μg/l)	As (μg/l)	Ni (μg/l)	Cu (μg/l)	Mg (μg/l)	Fe (μg/l)	Pb (μg/l)	Ca (mg/l)	Cr (μg/l)
1.17	0	----	613	46	28	15	42	568	1066	351	15.8	24
3.17	0	----	409	154	0	17	39	535	1269	320	14.7	17
4.50	0	----	380	21	75	14	36	550	1151	365	14.3	22
1.17	5	0.23	2710	26	18	41	43	1046	1318	277	34.1	50
3.17	5	0.63	4030	15	10	150	60	1893	2725	354	50.3	188
4.50	5	0.90	554	8	77	15	34	470	1029	233	13.0	15
1.17	10	0.12	285	11	32	11	36	345	1180	223	10.3	12
3.17	10	0.32	213	13	32	12	33	409	1107	265	11.3	13
4.50	10	0.45	389	6	65	14	32	441	1080	242	12.0	18
1.17	15	0.08	222	13	0	12	35	436	1091	248	12.3	13
3.17	15	0.21	243	14	0	14	43	483	988	272	12.4	14
4.50	15	0.30	338	8	67	24	35	464	1191	218	12.2	22
1.17	30	0.04	383	18	0	19	36	460	1429	254	12.4	16
3.17	30	0.11	239	14	4	33	38	458	1661	265	12.0	13
4.50	30	0.15	466	15	13	111	28	503	977	247	13.6	19
1.17	60	0.02	353	14	0	16	33	430	1155	208	11.2	18
3.17	60	0.05	377	11	0	22	36	498	1967	242	12.3	19
4.50	60	0.08	197	11	65	16	32	460	779	220	11.7	18
1.17	120	0.01	331	12	46	13	36	433	1035	204	11.2	14
3.17	120	0.03	213	16	0	20	42	444	1065	194	10.7	14
4.50	120	0.04	265	10	49	11	24	402	537	148	10.7	15

* Sample Location: Lake Eola, North Storm Date: 7/8/79

TABLE B-13

GENERAL WATER QUALITY DATA FOR COLUMN STUDY NUMBER 7*

Port (ft)	Time (min)	Vel. (ft/min)	TSS (mg/l)	VSS (mg/l)	NVSS (mg/l)	COD (mg/l)	TKN-N (mg/l)	NH_3-N (mg/l)	TOC-C (mg/l)	TP-P (mg/l)
1.17	0	----	65	21	44	90	1.05	.229		.155
3.17	0	----	58	22	36	56.3	.84	.153		.151
4.50	0	----	61	25	36	84.38	.77	.121		.151
1.17	5	0.23	45	17	28	78.75	.7	.175		.100
3.17	5	0.63	48	20	28	84.38	.7	.096		.144
4.50	5	0.90	49	21	28	84.38	.84	.080		.103
1.17	10	0.12	41	15	26	93.75	.84	.128		.103
3.17	10	0.32	43	18	25	84.38	.84	.112		.107
4.50	10	0.45	48	19	29	103.13	.77	.144		.134
1.17	15	0.08	33	11	22	56.25	.63	.144		.077
3.17	15	0.21	43	17	26	84.38	.84	.096		.233
4.50	15	0.30	41	17	24	78.75	.77	.112		.103
1.17	30	0.04	26	11	15	62.63	.63	.128		.077
3.17	30	0.11	37	14	23	56.25	.7	.144		.247
4.50	30	0.15	38	15	23	75	.63	.144		.114
1.17	60	0.02	25	13	12	71.25	.84	.049		.074
3.17	60	0.05	24	11	13	84.38	.98	.071		.233
4.50	60	0.08	25	12	13	71.25	.7	.058		.110
1.17	120	0.01	19	12	7	75	2.31	.049		.063
3.17	120	0.03	59	29	30	150	.35	.112		.209
4.50	120	0.04	23	11	12	65.63	.77	.033		.084

* Sample Location: George Stuart   Storm Date: 7/12/79

TABLE B-14

METALS DATA FOR COLUMN STUDY NUMBER 7*

Port (ft)	Time (min)	Vel. (ft/min)	Zn (μg/l)	Cd (μg/l)	As (μg/l)	Ni (μg/l)	Cu (μg/l)	Mg (μg/l)	Fe (μg/l)	Pb (μg/l)	Ca (mg/l)	Cr (μg/l)
1.17	0	----	531	9	72	14	132	683	848	378	30.4	24
3.17	0	----	392	12	0	21	124	750	819	376	29.5	38
4.50	0	----	298	12	131	25	122	711	886	403	26.5	32
1.17	5	0.23	555	5	128	20	112	679	792	336	26.4	25
3.17	5	0.63	497	11	0	21	129	819	987	391	30.1	40
4.50	5	0.90	1085	6	133	21	114	757	710	284	26.2	25
1.17	10	0.12	421	8	124	16	109	680	836	318	24.9	28
3.17	10	0.32	1635	6	75	15	104	1666	781	322	35.5	24
4.50	10	0.45	359	11	160	23	113	661	892	335	24.1	26
1.17	15	0.08	373	5	14	18	103	658	713	283	23.7	24
3.17	15	0.21	681	9	88	28	110	677	781	330	24.5	26
4.50	15	0.30	479	12	205	26	113	689	844	352	25.4	34
1.17	30	0.04	403	8	109	17	96	677	774	283	24.5	26
3.17	30	0.11	262	6	154	21	109	634	734	294	22.1	24
4.50	30	0.15	850	9	140	35	117	732	883	324	25.6	28
1.17	60	0.02	471	7	0	14	100	745	715	289	25.6	27
3.17	60	0.05	372	9	132	20	109	651	758	307	23.4	25
4.50	60	0.08	1250	9	189	27	115	887	746	316	31.7	29
1.17	120	0.01	1224	9	121	50	96	756	670	276	27.9	31
3.17	120	0.03	661	30	161	23	154	844	902	381	26.7	30
4.50	120	0.04	865	6	141	24	129	880	831	305	27.0	28

* Sample Location: George Stuart Storm Date: 7/12/79

APPENDIX C

TABLE C-1

SUMMARY OF MASS RATIOS OF CONSTITUENTS REMOVED FROM LAKE EOLA STORMWATER DUE TO 60 MINUTES OF SETTLING AT A DEPTH OF 1.1 FEET

(1) Storm-water Runoff Constituents	Average Initial Concentration (mg/l)	Final Concentration (mg/l)	Initial Minus Final Concentration (mg/l)	Ratio of Mass Removed of Constituents in Column 1 to Mass Removed of:					
				TSS	VSS	COD	NH_3	TOC	TP
TSS	145.9	68.86	77.04	1.0	1.34	1.27	412.0	2.34	261.2
VSS	89.9	32.36	57.54	0.75	1.0	0.95	307.7	1.75	195.1
COD	168.9	108.09	60.81	0.79	1.06	1.0	325.2	1.85	206.1
NH_3	0.5	0.313	0.187	0.0024	0.0032	0.0030	1.0	0.0057	0.63
TOC	139.9	107.02	32.88	0.57	0.57	0.54	175.8	1.0	111.5
TP	1.0	0.705	0.295	0.0038	0.0050	0.0050	1.58	0.0090	1.0

TABLE C-2

SUMMARY OF MASS RATIOS OF CONSTITUENTS REMOVED FROM LAKE EOLA STORMWATER DUE TO 60 MINUTES OF SETTLING AT A DEPTH OF 3.0 FEET

(1) Storm-water Runoff Consti-tuents	Average Initial Concen-tration (mg/l)	Final Concen-tration (mg/l)	Initial Minus Final Concen-tration (mg/l)	Ratio of Mass Removed of Constituents in Column 1 to Mass Removed of:					
				TSS	VSS	COD	NH_3	TOC	TP
TSS	145.9	71.78	74.12	1.0	1.65	2.13	430.93	1.53	5701.53
VSS	89.9	44.86	45.04	0.61	1.0	1.29	261.86	0.93	3464.62
COD	168.9	134.11	34.79	0.47	0.77	1.0	202.27	0.72	2676.15
NH_3	0.5	0.328	0.172	0.0023	0.0038	0.0049	1.0	0.0035	13.23
TOC	139.9	91.35	48.55	0.66	1.08	1.40	282.27	1.0	3734.62
TP	1.0	0.987	0.013	0.0001	0.0003	0.0004	0.0756	0.0003	1.0

TABLE C-3

SUMMARY OF MASS RATIOS OF CONSTITUENTS REMOVED FROM LAKE EOLA STORMWATER DUE TO 60 MINUTES OF SETTLING AT A DEPTH OF 4.5 FEET

(1) Storm-water Runoff Constituents	Average Initial Concentration (mg/l)	Final Concentration (mg/l)	Initial Minus Final Concentration (mg/l)	Ratio of Mass Removed of Constituents in Column 1 to Mass Removed of:						
				TSS	VSS	NVSS	COD	NH_3	TOC	TP
TSS	145.9	71.64	74.26	1.0	1.71	3.53	1.59	1142.5	27.92	94.76
VSS	89.9	46.39	43.51	0.59	1.0	2.07	0.93	669.4	16.36	57.55
NVSS	56.0	34.94	21.06	0.28	0.48	1.0	0.45	324.0	7.92	27.85
COD	168.9	122.28	46.62	0.63	1.07	2.21	1.0	717.2	17.53	61.67
NH_3	0.5	0.435	0.065	0.0009	0.0015	0.003	0.0014	1.0	0.024	0.086
TOC	139.9	137.24	2.66	0.036	0.061	0.13	0.057	40.9	1.0	3.52
TP	1.0	0.756	0.244	0.0033	0.0056	0.011	0.0052	3.75	0.092	1.0

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